PRODUCTIVITY GROWTH PATTERNS IN U.S. FOOD MANUFACTURING: CASE OF MEAT PRODUCTS INDUSTRY

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Abstract

A panel constructed from the Census Bureau's Longitudinal Research Database is used to measure total factor productivity growth at the plant-level and analyzes the multifactor bias of technical change for the U.S. meat products industry from 1972 through 1995. For example, addressing TFP growth decomposition for the meat products sub-sector by quartile ranks shows that the technical change effect is the dominant element of TFP growth for the first two quartiles, while the scale effect dominates TFP growth for the higher two quartiles. Throughout the time period, technical change is 1) capital-using; 2) material-saving; 3) labor-using; and, 4) energy-saving and becoming energy-using after 1980. The smaller sized plants are more likely to fluctuate in their productivity rankings; in contrast, large plants are more stable in their productivity rankings. Plant productivity analysis indicate that less than 50% of the plants in the meat industry stay in the same category, indicating considerable movement between productivity rank categories. Investment analysis results strongly indicate that plant-level investments are quite lumpy since a relatively small percent of observations account for a disproportionate share of overall investment. Productivity growth is found to be positively correlated with recent investment spikes for plants with TFP ranking in the middle two quartiles and uncorrelated with firms in the smallest and largest quartiles. Similarly, past TFP growth rates are positively correlated with future investment spikes for firms in the same quartiles.

Key Words: Total Factor Productivity Growth, Input Bias of Technical Change, Lumpy Investment, U.S. Meat Products Manufacturing

JEL Codes: D24, D92, L66

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I. Introduction

Recent studies in the analysis of productivity changes find that there are serious problems in dealing with aggregate measures of productivity. These studies indicate that the analysis of a sector or an industry focusing only on aggregate productivity measures may be misleading, presenting a simplistic explanation of the process. Dhrymes and Bartelsman (1998) and Dhrymes (1991) find that two-digit industry wide productivity, and its growth over time, may be reduced considerably upon addressing the four-digit industry composition of the sample. Hence, a disaggregated analysis can provide a more detailed perspective of the dynamics of TFP growth when compared with the aggregate level analysis of TFP growth. This paper analyzes the productivity patterns in the Meat Products Industry by addressing the measurement issues and productivity growth implications when an individual plant is considered as a decision-making unit.

The U.S. meat products sub-industry is a significant sub-industry within the food and kindred products industry. This sub-industry has the highest average employment accounting for 19% of total industry's average employment, the highest total value of shipments with 21.1% of total industry' total value shipments, the highest material input expenditure as a 28.6% of total industry's material expenditure, the highest labor expenditure as a 25.2% of total industry's labor expenditure, and the highest percent of total surviving plants (together with Grain Mill products sub-industry) with 16% when compared with the other sub-industries.

In the meat products sub-industry, increased consolidation and concentration over the past two decades has raised great concern for policy makers. This issue has existed since the late 1980s but it has became a greater concern in the early 1990s with the development of new production processes and products ("boxed beef" production) and lower red meat demand leading to another wave of consolidation [Paul (2001)]. While the four largest firms managed 36% of slaughter in 1960, only three firms managed the 81% of slaughter in 1994. In addition to these structural developments of the industry, mergers and acquisitions activities in the meat and poultry firms increased over the 1977-1982 period (Nguyen and Ollinger, 2002).

Increased concentration and related merger and acquisitions activities for these industries may indicate the monopsony and monopoly power, specifically, in the meat slaughter plants. As a result of these market structures animal producers could be harmed as processors pay low input prices to suppliers and consumers could be harmed by having charged higher prices while firms generate excess profits. Recent studies have focused on merger and acquisition activities and the relationship to productivity focusing on the food industry using plant-level data taken from the LRD. McGuckin and Nguygen (1995) analyze the U.S. food and beverage industry to study the relationship between ownership change and productivity for the period 1977-1987, finding that ownership change is related positively to both initial productivity and productivity growth after acquisitions. Their study indicates that the ownership change is negatively related to initial productivity for a sample of large continuing production plants, but positively related for smaller plants. The most recent study by Nguyen and Ollinger (2002) investigates the relationship between the merger and acquisitions activity and productivity performance of plants in meat packing (SIC 2011), sausages and other prepared meats (SIC 2013) and poultry slaughtering and processing (SIC 2015) sub-industries for the period 1977-1992. They find that firms in the meat and poultry products industries preferred to acquire highly productive plants. Their study indicates that during the post-merger period acquired plants experienced significant improvements in productivity (except for those in the poultry slaughtering and processing industry). They conclude that important motives for mergers and acquisitions are the synergies associated with firm managers achieving efficiency gains by combining the business of the acquired and acquiring firms and they place less emphasis on the proposition that a drive for monopoly power encourages merger and acquisitions.

Paul (2001) investigates the determinants and impacts of input and output market power patterns in the U.S. meat packing industry and finds significant but a declining market power and cost economies in the industry. Finding strong evidence of markups of output price from monopoly power and a weak evidence of markdowns from monopsony behavior in livestock input markets, Paul notes that increasing size of establishments and the resulting concentration in the industry may be the consequence of scale economies arising from technological factors embodied in plant and equipments. These results show that the increased consolidation and concentration trend for this industry has been motivated by cost economies, but the future potential is restricted by the existence of meager excess profits and few opportunities to take further advantage of cost economies.

In another study, Paul (2001) investigates the market and cost structure of U.S. beef packing industry at the plant-level and finds the absence of excess profitability in the industry suggesting that the market power and consolidation may be due to effective competition driving a monopolistically competitive or contestable markets type of equilibrium. She suggests that the increase in the size of plants and firms from the beef packing plants indicates the efficiency potential from scale, scope, multi-plant and other types of cost economies that can allow larger and more diverse or specialized plants or firms to increase their cost effectiveness. Paul's estimates indicate that there is little impact on depressing cattle prices or generating excess profits but significant cost (utilization scale and scope) economies exist in this industry. Furthermore, larger and more diversified plants embody even more potential technological economies than smaller plants.

Recent studies in meat products sub-industry lead us to investigate the productivity issues in more detail relating to recent changes in the industry. Precise measurement of productivity growth contributes to understanding the important issues motivating merger and acquisition activities and how market power is exercised by characterizing the industry's general structure based on the analysis of the plants and firms size, age and other characteristics.

II. Nature and Significance of the Problem

Accurate measurement of productivity growth plays a critical role in contributing to the future decision-making in industry and government policy-making strategies. In a productivity growth analysis of a sector or an industry, considering the individual plant as a decision unit contributes to our understanding of productivity growth. The most common method used in the literature is the representative agent framework, which has been widely applied in various sectors and industries. Nevertheless, this approach has some limiting assumptions such as frictionless adjustment in factor shocks, competitive product and factor markets, and identical constant returns technologies at all plants. Studies find that violations of any of these assumptions can lead to procyclical bias in measured productivity growth and systematic under- or over-statements (see Nelson, 1981; Berndt and Fuss, 1986; Hall, 1988; Morrison, 1989). Also, improvements in the exploitation of scale economies makes it difficult to distinguish the contributions of productivity improvements common to all plants from the contributions of heterogeneity effects which are attributed to entry, exit, diffusion, and plant-specific scale effects of learning (Roberts and Tybout, 1996). These issues can be addressed by examining the plant-level data, which also provides a better understanding for the aggregation problems in total productivity growth measurement. Analyzing productivity growth at the plant level provides the flexibility to compare the behavior of each plant throughout the time period as well as our understanding of the aggregate level of productivity growth of the firms in the industry.

Empirical analysis of the productivity transition of plants employs the Longitudinal Research Database in the U.S. Census Bureau containing the establishment-level production data from the Annual Survey of Manufacturers and Census of Manufacturers. This non-publicly available Census data is used in this study for understanding the productivity patterns and analyzing the aggregation issues in productivity measurement and the performance at the meat products sub-industry plant level.

Existing Economic Models

Better understanding of sector-wide performance can be realized focusing on the disaggregated plant-level dynamics of productivity. Studies focusing on the theoretical frameworks in industry dynamics [i.e., Jovanovic (1982), Hopenhayn (1992), Ericson and Pakes (1995)] try to explain how plants or firms in the industry with differing productivities can exist, and why entry and exit can occur simultaneously. Many micro-level empirical studies analyze the range of issues related to productivity dynamics following the theoretical framework of industry dynamics developed by Jovanovic, Hopenhayn, Ericson and Pakes [see Baily, Hulten and Campbell (1992), Pakes and Ericson (1989), Olley and Pakes (1992), Hall and Mairesse (1995), Bahk and Gort (1993), Dunne et al. (1989) and Baldwin and Gorecki (1991)].

Baily, Hulten and Campbell (1992) focus on the cross-sectional distribution in productivity at the plant level in the manufacturing sector and discuss how changes in this distribution along with changes in market shares influences aggregate productivity. Their study shows that entry and exit play only a very small role in industry growth over five-year periods and that increasing shares of output in high-productivity plants and decreasing shares of output in low-productivity plants are important to the growth of manufacturing productivity.

Bartelsman and Dhrymes (1998) analyze empirically the behavior of cross-sectional distribution of productivity using TFP measures derived from production functions, Solow-residual and Corrected-Solow residual-derived measure of TFP, and then compare their behavior over time using non-parametric tools. They compare the average TFP, which has grown substantially over the time period, with average plant level TFP, which has declined or remained flat. In contrast to Baily, Hulten and Campbell (1992), Bartelsman and Dhrymes show their results vary by the TFP measurement method. Using transition matrices to examine the persistence of plant productivity, they find that transition probabilities vary by industry, plant age, and other characteristics. Although various studies document the plant-level productivity transitions over time and investigating the heterogeneous plant level characteristics in the productivity analysis [such as Bartelsman and Dhrymes (1998), Baily, Hulten and Campbell (1992)], this paper differs from these studies by focusing on the disaggregated industry sample design and emphasizing the detailed TFP growth analysis via decomposing TFP growth by scale and technical change effects.

III. Methodology

There are three static methodologies measuring productivity in the literature which can be categorized into three approaches: i) index-number approach, ii) explicit specification of a production function and direct linkage of productivity growth to the parameters of this production function, and iii) the measurement of productivity based on the cost function model. This paper explicitly specifies a production function and direct linkage of productivity growth to the parameters of this production function is used. Total factor productivity measurement has been widely used in the literature starting from the early work of Solow (1957) known as the "Solow residual". Later, TFP is calculated using the econometric approach. The econometric approach estimates the underlying parameters based on the production function. This involves the explicit specification of a production function and the direct linkage of productivity growth to the parameters of this production function. In general, the production function is defined as

$$Q_{it} = F_i(X_{i1}, ..., X_{in}, t)\,. \tag{1}$$

where t denotes the time period, Q_{it} denotes output of plant i in period t, and X_{ij} denotes the level of inputs j of plant i , j=1,…,n. Following the well-known approach of decomposing TFP growth, totally differentiating (1) and dropping the subscripts i and t yields:

$$dQ = \sum_{j=1}^{n} F_{X_j} dX_j + F_t\, dt \tag{2}$$

Dividing (2) through Q and dt and rearranging the terms yields;

$$\frac{dQ_t}{dt}\frac{1}{Q_t} = \frac{d\ln Q_t}{dt} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \frac{d\ln X_j}{dt} + \frac{F_t}{Q}. \tag{3}$$

which can also be written as

$$\hat{Q} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \hat{X}_j + \hat{A} \tag{4}$$

where "^" indicates proportional growth rates $\left(\text{i.e., } \hat{Q} = \frac{\dot{Q}}{Q}\right)$ and $\hat{A} = \frac{F_t}{Q}$ represents the proportional shift in the firm specific production function due to the exogenous technical change. Then multiplying and dividing equation (4) through $\sum_{j=1}^{n} F_{X_j} X_j$ leads to

$$\hat{Q} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \left[\sum_{j=1}^{n} \frac{F_{X_j} X_j}{\sum_{j=1}^{n} F_{X_j} X_j} \hat{X}_j \right] + \hat{A} \tag{5}$$

The elasticity of scale is defined as $\varepsilon = \sum_{j=1}^{n} \varepsilon_j$ where $\varepsilon_j = \frac{F_{X_j} X_j}{Q}$ therefore $\varepsilon = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q}$, the sum of all production elasticities and measures returns to scale of the technology. An aggregate input is created using the divisia form $\hat{F} = \sum_{j=1}^{n} \frac{w_j X_j}{C} \frac{d \ln X_j}{dt}$.

In the absence of prices, we can use the first order conditions of cost minimization where $w_j = \frac{\partial C}{\partial Q} F_{X_j}$, which also implies that total costs, *C*, can be expressed in terms of the production function parameters

$$C = \sum_{j=1}^{n} w_j X_j = \sum_{j=1}^{n} \frac{\partial C}{\partial Q} F_{X_j} X_j = \frac{\partial C}{\partial Q} \sum_{j=1}^{n} F_{X_j} X_j \ . \tag{6}$$

The aggregate input term is defined

$$\hat{F} = \sum_{j=1}^{n} \frac{w_j X_j}{C} \frac{d \ln X_j}{dt} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{\sum_{j=1}^{n} F_{X_j} X_j} \hat{X}_j \tag{7}$$

where the marginal cost term, $\frac{\partial C}{\partial Q}$, cancels out. Using equation (7) in (5) leads to proportional actual output growth being written as

$$\hat{Q} = \sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \hat{F} + \hat{A} \tag{8}$$

where $\sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} \hat{F}$ is the scale effect (input growth), $\hat{A}$ is the exogenous technological change effect.

Total factor productivity growth ($\hat{TFP}$) is defined as the residual growth in output, not accounted for by the growth in inputs,

$$\hat{TFP} = \hat{Q} - \hat{F}\ . \tag{9}$$

Inserting equation (5) in equation (9) represents the total factor productivity growth expressed in terms of the production function specification as

$$\hat{TFP} = (\varepsilon - 1)\hat{F} + \hat{A} = \left(\sum_{j=1}^{n} \frac{F_{X_j} X_j}{Q} - 1 \right) \sum_{j=1}^{n} \frac{F_{X_j} X_j}{\sum_{i=1}^{n} F_{X_j} X_j} \hat{X}_j + \hat{A}\ . \tag{10}$$

Measuring Input Bias of Technical Change

The multifactor input bias measure are introduced by Binswanger (1974) using the changes in factor cost shares attributed to technical change. Antle (1984) develops a profit-based multifactor measure of biased technical change, which is equivalent to the cost-share approach. Following the Antle (1984) multifactor measure of input bias, define the *jth* production elasticity share as $\varepsilon_j / \varepsilon$ where $\varepsilon_j = \dfrac{F_{X_j} X_j}{F}$, F_{X_j} is the marginal product of X_j and $\varepsilon = \sum_{j}^{n} \varepsilon_j$. The impact of technical progress on input decisions for factor *j* can be attributed to exogenous technical change, measured by

$$B_{jt} = \frac{\partial \ln(\varepsilon_j / \varepsilon)}{\partial \ln T}. \tag{11}$$

The equation (11) indicates that exogenous technical change is biased towards the j^{th} factor (capital, labor, material, energy) if B_{jt} is positive (factor using), is biased against the j^{th} factor if B_{jt} is negative (factor saving), and is neutral if B_{jt} is equal to zero.

IV. Empirical Model Specification and Estimation

The empirical estimation specifies a quadratic production function.[1] The dependent variable $\ln Q_{it}$ is the output of plant i at time t and there are four inputs: capital, labor, materials and energy. Production function is specified as

$$Q_{it} = \alpha_o + \sum_{j=1}^{n} \alpha_j X_{itj} + \frac{1}{2}\sum_{j=1}^{n}\sum_{s=1}^{m} \alpha_{js} X_{itj} X_{its} + \beta_0 T + \frac{1}{2}\beta_1 T^2 + \sum_{j=1}^{n} \beta_j X_{itj} T \qquad (12)$$

where $j,\ s = K,L,M,E \quad \alpha_{js} = \alpha_{sj},\ j \neq s$. The problem of production function estimation with OLS is the potential endogeneity of input decisions as well as output. If there is unobserved heterogeneity across plants, the estimated coefficients from the regressions, which do not control fixed effects, will be biased. If time-invariant plant characteristics exist then failing to control for these characteristics when using pooled cross-section time series data will cause the error term, the dependent variable, and possibly several

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[1] The quadratic production function is the best fitting functional form for this sub-industry where the best functional form for the production function estimation chosen for the industry is based on the following criteria: positive marginal products, second order conditions satisfying the appropriate curvature conditions, an average returns to scale with a reasonable range (e.g., 0.5-1.5) and goodness-of-fit measurement. The quadratic production function is selected to be suitable for the meat products sub-industry with a 0.93 reasonable average returns to scale range and with a 0.90 R^2 measurement. Further, the percentage of observations with positive marginal products is 56% for K, 100% for both L and M, and 91% for E. The Hessian is negative semi-definite for a considerable percentage of the plant observations.

explanatory variables to be correlated over time. Therefore, plant-level fixed effects remove time-invariant differences in mean productivity across plants. The regression with plant-level fixed effects eliminates this potential source of bias.

While the balanced nature of the data set ensures the construction of capital stocks for plants using the perpetual inventory method to investigate investment spikes and lumpiness, it does not permit extensive modeling of the entry/exit process. The immediate consequence is that the estimated capital elasticity will be biased downward in accordance with the Olley and Pakes (1996) critique of the selectivity bias problem for balance data set which ignores the plant entry and exit processes.

The estimated coefficients using the fixed-effect regression with 4-digit industry dummies (4-digit composition of output) of the quadratic production function are used to generate the scale and technical change effects. Table A.1 in the Appendix presents the coefficient estimates, *t*-statistics, Breusch and Pagan Lagrange Multiplier test, Hausman test and their p-values based on the best-fitting production technology for meat products sub-industry.[2]

Figure 1 presents the annual average TFP growth. We compare the TFP, which is predicted by scale and technical change components using the production function estimation results, $(\varepsilon - 1)\hat{F} + \hat{A}$, with the TFP calculated using output growth (from the

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[2] Lagrange multiplier test for the random effect is applied to compare the OLS versus random effect model estimations. The null hypothesis is rejected for the industry suggesting that the classical regression model with single constant term is inappropriate and that the random effect model is preferred. Hausman specification test which assesses the equality of the coefficients estimated by the fixed- and random-effects estimators examines the appropriateness of the random-effect estimator under the assumption of a correctly specified model. Hausman test's null hypothesis is that the difference in coefficients (fixed and random effect model's coefficients) is not systematic (or individual effects are uncorrelated). The result is to reject null hypothesis. Based on these two tests, this study uses fixed effect regression in the production function estimation.

data) less aggregate input growth, $\hat{Y}-\hat{F}$, to find whether the residuals are over- or under-estimated. Figure 2 presents the mean residual graph for the meat products sub-industry. These results show that residuals are around zero and TFP is overestimated in 1976 and underestimated in 1977.[3]

Table 2 presents an overview of productivity changes of the meat products plants during the time period 1973-1995 summarizing the average TFP growth by periods. These results indicate that TFP growth follow a declining pattern even though growth remains positive during the time periods 1973-1995. During the time period 1986-1990, TFP growth is stable with almost 1% growth but TFP growth declines to 0.4% in the 1991-1995 period.[4] Overall, in the meat products sub-industry, average TFP growth rate of the plants starts with a 3.1 % growth rate and declines to 0.4% growth rate, averaging 1.5% growth.

Table 2. Average TFP Growth without Ranking Plants in Meat Products Sub-Industry

Time Period	Mean TFP Growth	Mean Scale	Mean Technical Change	Mean Returns to Scale
1973-1975	0.0305	-0.0102	0.0411	0.9156
1976-1980	0.0251	-0.0010	0.0264	0.8873
1981-1985	0.0098	-0.0055	0.0153	0.8992
1986-1990	0.0099	-0.0000	0.0099	0.9503
1991-1995	0.0044	0.0012	0.0032	1.0004
1973-1995	0.0147	-0.0025	0.0173	0.9319

Additional Table Notes: In Appendix, Table A.2 shows the detailed un-weighted mean TFP decomposition in each year.

[3] The residuals are usually around zero means that they are in the range of ± 5 percent deviation. If the residuals are out of this range according to the sign, we signify TFP is under-estimated or over-estimated.

[4] Table A.2 in the Appendix indicates that average TFP growth is positive except for years 1975, 1984 and 1994. In general, the industry follows a stable pattern over the time periods except a significant decline in the growth rate from 1974 to 1975, 1983 to 1984, and 1993 to 1994.

TFP Decomposition According to Quartile Ranks

Similar to Dhrymes's (1991) ranking procedure, this study applies the contemporaneous rank procedure to the TFP growth and its components to address the plant-level TFP growth in the meat products sub-industry. After calculating the TFP growth corresponding to a given plant, plants are ranked according to the magnitudes of their TFP, in each year. Then, plants are grouped according to these ranks by a quartile sampling procedure with 0 reflecting the lowest quartile group and 3 denoting the highest quartile. The analysis of the average TFP growth and its components (scale and technical change effect) in each rank for the meat products sub-industry is presented for the following time periods: 1973-1975; 1976-1980; 1981-1985; 1986-1990; 1991-1995.

Table 3 presents the average TFP growth and its components (scale and technical change effect) for each rank with an average returns to scale during the five prescribed time periods and indicates, on average, that the meat products sub-industry presents modest decreasing returns to scale except the highest ranked plants in 1991-1995 period (with scale elasticity at 1.06, on average). But, in general, average returns to scale per each rank over these ranks range from 0.89-0.95. Average returns to scale is calculated by finding the point estimates of the returns to scale for each plants and grouping them according to their TFP quartiles and then taking the average of each time period for each rank.

Table 3. Total Factor Productivity Growth Rankings and TFP Growth Components through 1973-1995

TFP RANK 0				
Time Period	TFP Growth	Scale Effect	Technical Change Effect	Average Returns to Scale
1973-1975	-0.1728	-0.1937	0.0209	0.8874
1976-1980	-0.0185	-0.0359	0.0174	0.8399
1981-1985	-0.0500	-0.0607	0.0107	0.8487
1986-1990	-0.0432	-0.0502	0.0070	0.9224
1991-1995	-0.0521	-0.0459	-0.0062	0.9685
1973-1995	-0.0582	-0.0672	0.0090	0.8939
TFP RANK 1				
Time Period	TFP Growth	Scale Effect	Technical Change Effect	Average Returns to Scale
1973-1975	0.0258	-0.0020	0.0278	0.9427
1976-1980	0.0146	-0.0044	0.0189	0.9023
1981-1985	0.0069	-0.0041	0.0111	0.9183
1986-1990	0.0035	-0.0019	0.0055	0.9497
1991-1995	0.0003	-0.0024	0.0026	0.9702
1973-1995	0.0089	-0.0030	0.0119	0.9361
TFP RANK 2				
Time Period	TFP Growth	Scale Effect	Technical Change Effect	Average Returns to Scale
1973-1975	0.0501	0.0062	0.0439	0.9536
1976-1980	0.0295	0.0024	0.0271	0.9224
1981-1985	0.0178	0.0025	0.0153	0.9203
1986-1990	0.0144	0.0032	0.0109	0.9561
1991-1995	0.0098	0.0035	0.0063	0.9996
1973-1995	0.0220	0.0034	0.0187	0.9502
TFP RANK 3				
Time Period	TFP Growth	Scale Effect	Technical Change Effect	Average Returns to Scale
1973-1975	0.2164	0.1466	0.0698	0.8827
1976-1980	0.0746	0.0335	0.0411	0.8873
1981-1985	0.0645	0.0401	0.0244	0.9088
1986-1990	0.0650	0.0487	0.0163	0.9756
1991-1995	0.0598	0.0496	0.0102	1.0638
1973-1995	0.0856	0.0565	0.0291	0.9490

Additional Table Notes: This decomposition according to quartile ranks for each year can be seen in Appendix, Tables A. 3a-A.3d.

Figure 3 presents the average productivity growth for each quartile group, the lowest graph corresponds to the first quartile (quartile 0), the next corresponds the second quartile (quartile 1) and so on. With this analysis we are able to classify plants exhibiting low TFP, average TFP and high TFP growth and investigate whether there is a considerable gap between the highest growth plants with the others. In the meat products sub-industry, the time profile of productivity growth for all quartile groups indicates that plants in the ranks 1 and 2 follow a similar pattern with an almost no gap between them. There is slight gap between their productivity growth patterns at the beginning of the period but this gap declines through the end of period. Throughout the time periods, the gaps between the highest-ranked plants (rank 3) and the others exist, particularly in contrast to the lowest ranked plants. But this gap becomes insignificant between the highest ranked plants and the plants that are in ranks 1 and 2 after 1975. In contrast, the gap between the lowest ranked plants exists throughout the time periods by a considerable amount especially until 1978. Also, the lowest ranked plants (rank 0) catch the plants that are in ranks 1 and 2 between 1977 and 1984. They decrease the gap significantly compared to the earlier years such as 1974, 1975 and 1976. These results indicate that even in the same sub-industry there is considerable variation in productivity measurements among plants. The results in the literature suggest the presence of stationary or slightly declining productivity in the middle to the late 1970s, and substantial growth following the 1980-81 recession. Our results show that the most productive plants (rank 3) fit this case and we can see relatively significant dynamic shifts in the productivity behavior at the plant level between the years 1973-1978 and after 1983 for the plants which are in the lowest (rank 0) and the highest ranks (rank 3) in the meat products sub-industry.

TFP growth components from Table 3 show that the scale effect has the most significant contribution to the TFP growth measurement for the plants in the lowest rank group (rank 0) throughout the whole period and the highest rank group (rank 3) except in the 1976-1980 period. These scale effect contributions to TFP measurement are in the opposite (negative) direction for the plants, which are in the lowest rank group (rank 0) and in the same direction (positive) for the plants, which are in the highest rank group (rank 3). For the group of plants, which are in ranks 1 and 2, technical change effect has the most significant contribution to the TFP growth measurement and their contributions to TFP measurements are in the same direction (positive) with TFP growth measurement for the both groups (see figures 4-7). Plants that are in the lowest and the highest ranked quartiles extract scale efficiencies over technological progress. For the lowest rank plants, this situation suggests that these plants cannot afford to realize higher productivity growth through technological adoption but they have the potential to reorganize input allocations to achieve productivity growth. The significance of technical change effect on TFP growth can be attributed to the food and kindred products industry's responsiveness to new technologies and becoming increasingly high-tech over past few decades in processing, packaging and marketing of food products. More specifically, in the meat industry, some 4-digit sub-groups such as sausages and other prepared meat products has been subject to new developments in packing and also meat packing plants has been subject to a new production processes like “boxed beef” production which make technical change component is an important factor for the TFP growth measurement in this industry.

V. Input Bias of Technical Change in Meat Products Sub-industry

Table 4 summarizes exogenous input bias results (see figure 8) and show that technical change is biased toward the capital input in a declining magnitude except in 1981-1985 but after this period, the magnitude increased significantly. For material input, technical change is biased against the materials input except in the period 1973-1975 with a relatively small and unchanging magnitude and toward the labor input with a fluctuating magnitude. The new products of "boxed beef" involve more trimming of carcasses which is necessarily labor intensive. The direction of technical change is energy-using after 1976-1980 with a decreasing magnitude.

Table 4. Multifactor Bias in Technical Change for Sub-Period Averages in Meat Products Sub-Industry

Time Period	Mean Capital Input	Mean Labor Input	Mean Materials Input	Mean Energy Input
1973-1975	4.8222	0.0421	0.0198	-0.3460
1976-1980	0.0561	0.0205	-0.0065	-0.0460
1981-1985	-0.5436	0.0137	-0.0142	0.2281
1986-1990	0.5940	0.0475	-0.0044	0.0933
1991-1995	0.1796	0.0123	-0.0072	0.0333
1973-1995	0.6912	0.0259	-0.0044	0.0220

Additional Table Notes: This result is also presented for each year in the Appendix, Table A.4.

VI. Plant's Size Effects to Productivity

Plants sizes are arranged into four categories with size A reflecting the smallest to size D for the largest plants. The direct size effects on TFP growth analysis is presented in table 5 indicates that the middle-sized plants (size B category) have the highest average growth rate for the 1973-1975 and 1976-1980 periods, the largest-sized plants (size category D) have the highest productivity growth for the 1981-1985 and 1986-1990 periods, and the plants that are in size category C have the highest productivity growth in the last period 1991-1995. Mainly, plants that are in size categories B and D have the highest average productivity growths through the time periods.

Table 5. Direct Effect of Size Categories to Average TFP Growth

	Size A (The Smallest)	Size B (Middle)	Size C (Middle-Larger)	Size D (The Largest)
Time Period	Average TFP	Average TFP	Average TFP	Average TFP
1973-1975	-0.0028	0.0524	0.0431	0.0314
1976-1980	0.0254	0.0302	0.0267	0.0183
1981-1985	-0.0143	0.0163	0.0178	0.0194
1986-1990	0.0021	0.0111	0.0117	0.0147
1991-1995	-0.0076	0.0092	0.0123	0.0035
1973-1995	0.0008	0.0213	0.0205	0.0162

Additional Table Note: TFP decomposition by plant size categories over time periods is presented in Appendix, Tables A.5a-A.5d.

The smallest sized plants (size category A) present the most fluctuating productivity patterns comparing the larger sized plants. The smaller plants are more likely to fluctuate in their productivity rankings; in contrast, large plants are more stable in their productivity rankings. Investigation of the technical change contribution on TFP growth across plant sizes presented in tables A.5 indicates that, on average, the smallest sized plants (size category A) have the highest technological change contribution on TFP growth in the same direction as TFP throughout the time periods.

Secondary Decomposition of TFP Growth based on Size Categories

The section investigates the detailed decomposition of TFP growth with respect to size groups. The different size groups are summarized in Table 6 for each TFP rank.

Table 6. Plant's Size Categories Effect on Average TFP Growth according to Productivity Rank Groups

TFP RANK 0				
Time Period	Size A (The Smallest)	Size B (Middle)	Size C (Middle-Larger)	Size D (The Largest)
1973-1975	-0.7034	-0.0275	-0.0036	0.0008
1976-1980	-0.0285	-0.0173	-0.0136	-0.0154
1981-1985	-0.1469	-0.0272	-0.0152	-0.0136
1986-1990	-0.0492	-0.0289	-0.0410	-0.0540
1991-1995	-0.0628	-0.0278	-0.0246	-0.0955
1973-1995	-0.1542	-0.0256	-0.0210	-0.0387
TFP RANK 1				
Time Period	Size A (The Smallest)	Size B (Middle)	Size C (Middle-Larger)	Size D (The Largest)
1973-1975	0.0230	0.0279	0.0264	0.0260
1976-1980	0.0137	0.0156	0.0145	0.0145
1981-1985	0.0059	0.0077	0.0068	0.0071
1986-1990	0.0028	0.0039	0.0037	0.0038
1991-1995	-0.0010	0.0005	0.0008	0.0006
1973-1995	0.00764	0.0097	0.0090	0.0091
TFP RANK 2				
Time Period	Size A (The Smallest)	Size B (Middle)	Size C (Middle-Larger)	Size D (The Largest)
1973-1975	0.0497	0.0506	0.0504	0.0496
1976-1980	0.0305	0.0294	0.0297	0.0283
1981-1985	0.0181	0.0182	0.0174	0.0178
1986-1990	0.0135	0.0140	0.0145	0.0143
1991-1995	0.0096	0.0094	0.0100	0.0104
1973-1995	0.0221	0.0220	0.0221	0.0218
TFP RANK 3				
Time Period	Size A (The Smallest)	Size B (Middle)	Size C (Middle-Larger)	Size D (The Largest)
1973-1975	0.1942	0.4643	0.0966	0.1105
1976-1980	0.0768	0.0711	0.0698	0.0807
1981-1985	0.0759	0.0546	0.0592	0.0687
1986-1990	0.0678	0.0594	0.0589	0.0741
1991-1995	0.0695	0.0598	0.0559	0.0541
1973-1995	0.0884	0.1138	0.0656	0.0748

Additional Table Notes: TFP and Size decomposition categories over time periods is presented in Appendix, Tables A.6a-A.6d.

The table shows that the middle-larger sized plants (size category C) present the highest average TFP growth (albeit negative) within TFP rank 0. For the TFP rank 1 category, on average, plants in size categories B, C and D are very close with respect to their productivity growth and the size effect can be seen in those plants in categories B, C and D. Among those plants middle-sized plants (size category B) have the highest TFP growth except the time period 1991-95. For the TFP rank 2 category, on average, plants that are in all different size categories have similar productivity growth levels of 2.2%, indicating no size effect for the TFP rank 2. For the TFP Rank 3 category, on average, plants which are in size category B (middle-sized plants) with 11.4% productivity growth play a dominant role with respect to productivity growth among other size categories. The plants in size categories A, D and C follow the plants in the size category B based on their average productivity growth indicating the size effect is evident for the plants in TFP rank 3. Therefore, investigation of the size effect on TFP categories indicates that plants in size category B (middle-sized plants) are the effective ones with respect to productivity growth for ranks 1, 2 and 3 but plants in size categories B and D are robust across size categories since they present similar productivity growth on average. The smallest sized plants only perform well in terms of productivity growth in TFP rank 2. In general, the size effect can be seen in TFP rank 1 with robust productivity across size categories B, C and D and in TFP rank 3 with a significant productivity in size category B compared with the other size categories.

VI. Plant Productivity Transitions

This section analyzes plants' productivity transitions between periods to assess whether plants occupy a fixed rank with respect to their productivity levels or vary in their productivity rankings. Transition matrices are constructed to address plant switching behavior based on quartile ranks. The transition matrices are organized by assigning a plant to a quartile group in the cross sectional distribution of TFP in each year based on the value of its TFP measure and then tabulating the incidence of transition of plants from quartile *q(t)* in a year t to quartile *q(t+5)* in year *t+5*; i.e., this is a *4x4* matrix with each element presenting the proportion of plants making the transition from quartile *i* to quartile *j* over a five period (*i, j* = 0,1,2,3 quartiles).

Table 7 presents number of times in plants' productivity transitions and their corresponding percentages in five-year periods from 1976 to 1991. Using the dummy variable approach to capture the differences in the age of plants, we can only assign approximate age variable for the plants in our sample comparing the plants which exist in earlier years (1963 or 1967) to the plants that have already in existence in 1972. For example, since LRD does not contain ASM panels prior to 1969, if a plant was not included in 1963 Census but was included in 1967, the plant could be anywhere from five to nine years old in 1972. Therefore, exact age cannot be constructed for the plants that are already in existence in 1972. Similar to the Doms and Dunne (1994) approach, this study assigns the dummy variables as follows: DA1: if plant exists in 1963-- 9 years old plant when we compare with year 1972, DA2: if plants exists in 1967--around 5 year old plant (but it could be anywhere between 5 to 9 years old age), and the remaining plants are born in 1972 (considered the youngest plants in our sample period).

Table 7. Plant Productivity Quartile Category Switching Percentages in overall and across Age Categories

	No Switching	Switching Once	Switching Twice	Switching Three Times
All Industry	0.09	0.25	0.37	0.29
Age 1	0.12	0.18	0.38	0.32
Age 2	0.09	0.29	0.33	0.29
Age 3	0.08	0.26	0.38	0.29

In the meat products sub-industry, 9% of the plants do not change their productivity rankings throughout the time period. This percentage declines slightly when the plants get older and 25% of the meat sub-industry plants switch once while 18% of the youngest plants, 29% of the middle-aged plants and 26% of the oldest plants switch once. Considering all age categories and the plants pooled together for this sub-industry, the percentage of plants switching twice is 37% of all plants, 38% of the youngest plants, 33% of the middle-aged plants, and 38 % of the oldest plants throughout the time periods, suggesting considerable movement in plants' productivity categories for this industry.

The following table presents the summary of plants' productivity transitions through the time periods in the meat products sub-industry and the transition of plants' productivity across age categories. Similar to Barteslman and Dhrymes (1998), these transition tables present as **Gain** to indicate productivity improvements by one or more quartile ranks, as **Lose to** indicate plants' productivity transition downward by one or more quartile ranks, and as **Stay** to indicate plants remaining at the fixed rank throughout the selected time period.

Table 8. Meat Sub-Industry Plants' Productivity Transition Behaviors in overall and across Age Categories

1976 vs. 1981

	Gain			Lose			Stay			
	Rank 0	Rank 1	Rank 2	Rank 1	Rank 2	Rank 3	Rank 0	Rank 1	Rank 2	Rank 3
All Industry	0.53	0.40	0.23	0.27	0.33	0.61	0.47	0.33	0.44	0.39
Age 1	0.20	0.27	0.18	0.36	0.45	0.70	0.80	0.36	0.36	0.14
Age 2	0.33	0.28	0	0	0.43	0.75	0.67	0.72	0.57	0.25
Age 3	0.59	0.47	0.30	0.30	0.27	0.54	0.41	0.23	0.43	0.46

1981 vs. 1986

	Gain			Lose			Stay			
	Rank 0	Rank 1	Rank 2	Rank 1	Rank 2	Rank 3	Rank 0	Rank 1	Rank 2	Rank 3
All Industry	0.60	0.38	0.29	0.27	0.38	0.64	0.40	0.35	0.33	0.34
Age 1	0.36	0.35	0.17	0.21	0.50	1.00	0.37	0.43	0.33	0
Age 2	1.00	0.30	0.33	0.50	0.50	0.50	0	0.20	0.17	0.50
Age 3	0.63	0.44	0.31	0.20	0.33	0.61	0.37	0.36	0.36	0.38

1986 vs. 1991

	Gain			Lose			Stay			
	Rank 0	Rank 1	Rank 2	Rank 1	Rank 2	Rank 3	Rank 0	Rank 1	Rank 2	Rank 3
All Industry	0.69	0.32	0.20	0.30	0.50	0.54	0.31	0.35	0.30	0.45
Age 1	0.63	0.31	0	0.46	0.88	0.75	0.36	0.23	0.12	0.25
Age 2	0.63	0.20	0	0.20	1.00	0.57	0.37	0.60	0	0.43
Age 3	0.73	0.33	0.24	0.30	0.41	0.50	0.27	0.37	0.35	0.47

Additional Table Notes: These transition tables are presented in detail for each year considering plants' ranks across all industry and age categories in the Appendix, Tables A.7, A.8, A.9, A.10.

Table 8 indicates that over half of the plants (53%) move up from rank 0 to improve their productivity from 1976 to 1981. During the same period, 40% of the plants in rank 1 improve their productivity and 27% of them drop in their productivity rank. Plants in rank 2 in the same time period find that 23% of them improve and 33% of them drop in their productivity rank and for plants in rank 3, 61% of them drop in their productivity rank.

During the time period 1981-1986, more than half of the plants in rank 0 (60%) improve their productivity, 38% of plants in rank 1 improve and 27% of these plants drop in their productivity rank. For the plants that are in rank 2, 29% of them improve and 38% of them drop in their productivity rank and 66% of plants in the rank 3 drop in their productivity rank. Similarly, during the time period 1986-1991, 69% of the plants in rank 0 improve their productivity, 32% of plants in rank 1 improve and 33% of them drop in, 20% of plants in rank 2 improve and 50% of them drop in their productivity ranks and 55% of plants in rank 3 plants drop in their productivity ranks. In no case, do 50% of the plants stay in the same category indicating considerable movement between productivity rank categories.

The analysis of the youngest plants indicates that 80% of the plants in the rank 0 stay in the same category during the time period 1976-1981, and for rest of the time periods, 36-37% of these plants stay in the same category. Plants in rank 3 for this age group indicate that there is considerable productivity movement downward. In particular, 70% of the plants in the 1976-1981 time period, all of the plants in the next time period, and 75% of the plants in the last time period move downward in their productivity rankings. The results indicate that 88% of the youngest plants in the TFP rank 2 declined in their productivity rankings during the end of the period. These results indicate that the youngest plants cannot sustain the highest rank (rank 3) and there is considerable movement in their productivity ranks.

The analysis of the plants which are in the age 2 groups shows that during the 1976-1981 time period, plants that are in ranks 0, 1 and 2 stay in their initial categories but for the rest of the time periods there exist a considerable movement in their productivity ranks except for the plants that are in rank 1 during the 1986-1991 time periods. For the plants in the oldest age group (age category 3), considerable movement across categories is observed. Less than half of the plants stay in the same category, and most of the plants switch categories throughout the time periods. Therefore, considerable productivity movement across age and productivity groups is observed for this sub-industry.

VII. Lumpy Investment in Meat Products Sub-Industry

This section focuses on the nature of lumpy investment at plant-level in the meat products sub-industry. The contribution of these large investment events to aggregate investments in the meat products sub-industry over the 24-year sample period is presented in Table 9 with the contribution of the ranked investment rates based on the type of investments to cumulative aggregate investment. In Table 9, the sum of the investment associated with each plant's largest investment episode accounts for 74% of cumulative aggregate machinery investment, 80% of cumulative aggregate buildings investment, and 74% of the combined cumulative aggregate machinery and building investments. The results show that even in the very first investment year, each plant has already accounted for more than 70% of cumulative aggregate investment. Power's (1994) study also found that plants in the food industry completed nearly all intense periods of investment within a year; she found that 70.3% of food plants have a one year spike duration, 18% of plants have two year spike duration. Power's study also finds that the first year of her sample has the highest percentage of observations which are investment spikes.

Table 9. Machinery, Buildings and Combined Investment Rate Analysis for each Rank

Ranks	Machinery Investment Fraction	Mean Machinery Investment	Buildings Investment Fraction	Mean Buildings Investment	Machinery and Buildings Investment Fraction	Mean Machinery and Buildings Investment
1	0.73532	14.7729	0.79575	12.2318	0.74319	13.8013
2	0.04250	0.8623	0.05101	0.7803	0.04524	0.8485
3	0.03240	0.6607	0.03624	0.5682	0.03343	0.6300
4	0.02571	0.5242	0.02586	0.3955	0.02582	0.4867
5	0.02078	0.4236	0.01963	0.3033	0.02079	0.3918
6	0.01754	0.3594	0.01548	0.2452	0.01734	0.3284
7	0.01528	0.3131	0.01203	0.1906	0.01469	0.2782
8	0.01377	0.2821	0.00959	0.1264	0.01298	0.2458
9	0.01248	0.2558	0.00760	0.1064	0.01141	0.2161
10	0.01118	0.2325	0.00596	0.0935	0.01025	0.1970
11	0.01007	0.2095	0.00472	0.0502	0.00915	0.1759
12	0.00913	0.1790	0.00381	0.0493	0.00818	0.1483
13	0.00829	0.1734	0.00304	0.0379	0.00739	0.1428
14	0.00759	0.1588	0.00243	0.0330	0.00666	0.1287
15	0.00676	0.1414	0.00192	0.0218	0.00598	0.1156
16	0.00607	0.1256	0.00153	0.0207	0.00532	0.1019
17	0.00548	0.1117	0.00115	0.0142	0.00474	0.0926
18	0.00483	0.1025	0.00083	0.0136	0.00417	0.0815
19	0.00415	0.0863	0.00055	0.0081	0.00363	0.0713
20	0.00350	0.0684	0.00037	0.0072	0.00307	0.0549
21	0.00283	0.0559	0.00025	0.0057	0.00252	0.0474
22	0.00218	0.0455	0.00013	0.0046	0.00198	0.0375
23	0.00149	0.0331	0.00008	0.0055	0.00138	0.0285
24	0.00067	0.0203	0.00003	0.0031	0.00071	0.0184

* Investment fractions for each rank is found as the sum of the investment associated with each plants' the highest (for rank 1), the second-highest (for rank 2), and so on, annual investment episode divided by the sum of each plant's total investment for the 24-year period (for example, the highest rank represents the average plant experiences a one year investment episode that accounts for 74% of its total investment spending over the 24 year interval).

** Mean Investment is calculated as: we rank investment rates for each plant from highest to lowest, such as rank 1 show the highest investment rate and 24 is the lowest, then mean investment rate shows the mean of these ranked investment rates so the rank 1 mean investment rate is the highest mean investment rate, next one shows the means of secondary largest investment rate, and so on.

There are two definitions to characterize lumpy investment spikes which are commonly considered in previous plant-level investment studies such as Power (1994), Cooper, Haltiwanger and Power (1999), and Nilsen and Schiantarelli (1998). The first definition is an absolute spike definition where the investment rate is considered to be lumpy if it exceeds a 20% change in the capital stock. As the previous studies indicated, this percentage hurdle is considered to eliminate routine maintenance expenditures implying that the lumpy investments are different from these expenditures. This percentage hurdle is somewhat arbitrary but studies find that the results are robust to a variety of other definitions of investment spikes [Cooper et. al. (1999) and McClelland (1997)].

The detailed study by Power (1994) describes the relative spike definition where the plant's investment is considered lumpy if it is large relative to that plant's other investments. She defines spikes as abnormally high investment episodes relative to the typical investment rate experienced within a plant and considers various hurdles over the median investment rates (such as 1.75, 2.5, 3.5 times of median investment rate) to reflect abnormally high investment episodes.[5] In this study, two alternative definitions, the absolute spike definition (20%) as well as the relative spike definition [2.5*(median investment rate)] are used to characterize investment behavior in the meat products manufacturing plants.

Table 10 presents the percentage of observations in the dataset which are counted as spikes and non-spikes and the contribution of investment spikes (and non-spikes) to aggregate investments in the meat products sub-industry according to the spike definitions. The results from this table show that even though the percent of observations

[5] Power (1994) indicates that absolute definition captures many smooth expansions which are ignored by the relative definition, the relative definition captures many investments which are large relative to the plants other investments, but not large in any absolute sense. An excellent extensive investigation of these alternative specifications of investment spikes and the comparisons can be found in Power (1994).

which are lumpy investments are lower than the percentage of non-spike investment observations across investment types and spike definitions, the percentage of total sample investment accounted for by lumpy investments is significantly greater than the one by the investments that are not lumpy. Thus, plant-level investment is quite lumpy since a relatively small percentage of observations account for a disproportionate share of overall investment. For example, 46% (17%) of the observations are counted as machinery investment spikes, but they account for 94% (84%) of aggregate investment according to the absolute (relative) spike definition. A similar pattern is revealed across investment types and spike definitions.

Table 10. Analysis of Investment Spike Characteristics in Meat Products Sub-Industry across Spike Definitions and Investment Types

Machinery Investment Rate			
Spike Definitions*	Percent of Observation in Data set which are spikes and non-spikes	Number of Observations which are spikes and non-spikes	Percent of Total Sample Investment Accounted for by spikes and non-spikes**
Absolute Spike	46 spike 54 non-spike	2187 spike 2535 non-spike	94.0 spike 6.0 non-spike
Relative Spike	17 spike 83 non-spike	822 spike 3900 non-spike	84.1 spike 15.9 non-spike
Buildings Investment Rate			
Absolute Spike	27 spike 73 non-spike	1256 spike 3466 non-spike	95.5 spike 4.5 non-spike
Relative Spike	35 spike 65 non-spike	1642 spike 3080 non-spike	97.4 spike 2.6 non-spike
Combined Machinery and Buildings Investment Rates			

Absolute Spike	39 spike 61 non-spike	1847 spike 2875 non-spike	93.2 spike 6.8 non-spike
Relative Spike	20 spike 80 non-spike	945 spike 3777 non-spike	86.7 spike 13.3 non-spike

*Absolute spike defined as investment rate that exceeds 20% and Relative spike defined as investment rate that exceeds [(2.5*median investment rate)].

** Percent of total sample investment accounted for by spikes is found by the ratio of investment spikes to total investment.

Additional Table Notes: Time series results of the investment spike contributions to aggregate investments and the fraction of plants that have lumpy investment episodes in each year presented in the Appendix, Table A.11.[6]

Recent findings indicate that fluctuations in aggregate investments are closely linked to the fraction of plants experiencing large investment episodes (Cooper, Haltiwanger and Power, 1999). For the meat products sub-industry, the time series fluctuations and relative importance of large investment episodes are plotted in Figures 9-11 and present the time series fluctuations in the fraction of plants with investment rates in excess of 20% of their contribution to aggregate investment.[7] The pattern of aggregate investment accounted for by investment spikes closely follows the fraction of plants presenting investment spikes. These plots indicate that the percent of plants exhibiting spikes, and the percent of total investment accounted for by spikes, experienced several small peaks and valleys over the sample period, especially after 1981.

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[6] These results indicate that, on average, plants with large machinery investment episodes constitute 45% (17%) of the plants but account for, on average, 72% (31%) of the machinery investment rate according to the absolute (relative) spike definition. Both lumpy and non-lumpy investments are important components of investment. Similarly, on average, plants with large buildings investment episodes constitute 26% (34%) of the plants but account for 72% (83%) of the buildings investment, based on absolute (relative) spike definition. Large episodes for combined machinery and buildings investments constitute, on average, 38% (19%) of plants and account 65% (37%) of the machinery and buildings investment rate based on absolute (relative) spike definition.

[7] Here we only present the graphs based on the absolute spike definition since the similar patterns that are seen in the graphs based on relative spike definition.

The fraction of plants presenting large investment episodes and the amount of investment accounted by such plants are positively correlated with the aggregate investment for both spike definitions. The correlation between the aggregate machinery investment rate and the fraction of plants with investment rates larger than [2.5*(medium investment rate)] is 0.62. The correlation between the aggregate machinery investment rate and the fraction of investment accounted for by plants with investment rates larger than [2.5*(medium investment rate)] is 0.57. For buildings investment rate these correlations are weaker, 0.48 and 0.38, respectively, and for machinery and buildings investment together it is 0.60 and 0.55, respectively. For the absolute spike definition these correlations are also weaker and for machinery 0.47 and 0.41, respectively; for buildings 0.53 and 0.43, respectively; and, for machinery and buildings together 0.48 and 0.41, respectively. The positive and strong correlations detected in machinery investment and machinery and buildings investments together for the relative spike definition indicate that the fluctuations in the aggregate investment are linked closely to the fraction of plants experiencing large investment episodes.[8]

Table 11 presents the number of investment spikes per plant and percentage of plants exhibiting investment spikes over the 24-year period to analyze the lumpy structure of the meat product sub-industry (see figures 12-13 in Appendix).[9]

Table 11. Number of Spikes and Percent of Plants in each Spike across Investment Types and Spike definitions

[8] The correlation between aggregated investment rates, fraction of plants with investment rate and investment accounted by these plants according to spike definitions are presented in the Appendix, Tables A.12a and A.12b.

[9] In this table, for each investment types there exist a low percentage of plants that has higher than the reported spike numbers but we don't report these numbers due to the confidentiality reasons.

ABSOLUTE SPIKE DEFINITION				RELATIVE SPIKE DEFINITION		
	Machinery Investment	Buildings Investment	Machinery and Buildings Investment	Machinery Investment	Buildings Investment	Machinery and Buildings Investment
SPIKES	Percent of Plants	Percent of Plants	Percent of Plants	Percent of Plants	Percent of Plants	Percent of Plants
0	99.02	99.51	99.02	99.02	99.51	99.02
1	1.47	1.96	1.47	3.92	1.47	3.43
2	0.49	0.98	0.98	4.9	0.98	3.92
3	0.98	4.9	0.98	22.06	2.45	12.26
4	0.49	12.8	3.43	32.84	4.9	25.98
5	1.96	14.7	3.92	23.04	4.9	24.02
6	14.7	16.7	6.37	8.33	12.26	16.67
7	4.41	18.6	10.29		11.77	8.33
8	6.37	14.2	12.75		12.75	
9	9.8	7.4	13.24		18.14	
10	15.7		11.28		10.78	
11	17.2		13.73		7.35	
12	10.8		10.78			
13	10.3					
14	10.3					

Most of the plants (99%) have at least one year without a lumpy investment episode. Based on the absolute spike definition, outside of zero, machinery investment spikes ranging from 1 to 14 account for 100% of plants indicating every plant have at least one spike any given year out of 24 year time period.[10] Those plants engaged in

[10] The maximum number of spikes observed are 19 (9) spikes for machinery investments, 12 (14) spikes for building investments, 16 (9) spikes for the combined machinery and building investments based on absolute (relative) spike definition but due to the confidentiality reasons we have only reported up to 14 (6) spikes for machinery investments, 9 (11) spikes for building investments and 12 (7) spikes for the combined machinery and building investments based on absolute (relative) spike definition in Table 11.

lumpy investment ranging from 1-19 different years with the median number of lumpy investment episodes is 7 times. Machinery investment spike episodes total 10-14 times over the 24-year period accounting for 64% of the plants. For building investment spikes, outside of zero, the spikes ranging from 1 to 9 times over the sample period and account for 92% of plants suggesting 8% (at most) of the plants never engage in lumpy investments. Of those plants engaged in lumpy investments ranging from 1-12 times, the median number of lumpy investment episodes are 3 and 9 times. Building investment spike episodes totaling 4-8 times over the 24-year period accounts for 77% of the plants. For the combined machinery and building investment spikes, outside of zero, spikes ranging from 1-12 times over the period, accounting for 89.2% of plants. Of those plants engaged in lumpy investments ranging from 1-16 times over the period, the median number of lumpy investment episodes are 5 and 13 times. The combined machinery and building investment spike episodes total 7-12 times over the 24-year period, accounting for 72 % of the plants.

Based on the relative spike definition, outside of zero, machinery investment spikes ranging from 1 to 6 times over the sample period, accounting for 95.1% of plants, suggesting that 1.5% (at most) of plants never engage in lumpy investments. Of those plants engaged in lumpy investments ranging from 1 to 9 times over the sample period, the median number of lumpy investment episodes is 2 times. Machinery investment spike episodes totaling 3-5 times over the 24-year period account for 78% of the plants. For building investment spikes, outside of zero, the spikes ranging from 1 to 11 times accounts for 88% of plants suggesting 2% (at most) of plants never engage in lumpy investments. Of those plants engaged in lumpy investments ranging from 1-14 times over the sample period, the median number of lumpy investment episodes are 4 and 5 times. Building investment spike episodes totaling 6-10 times over the 24-year period, account for 66% of the plants. For the combined machinery and building investment spikes, outside of zero, the spikes ranging from 1-7 times, accounts for 95%. Of those plants engaged in lumpy investments ranging from 1-9 times over the sample period, the median number of lumpy investment episodes is 7 times. The combined machinery and building investment spike episodes totaling 3-6 times over the 24-year period account for 79% of the plants. The results, presented in table 12, also indicate that there is a high correlation between the percent of plants that has various investment rates across spike definitions.

Table 12. Correlation between Percent of Plants in each Number of Spikes for Investment Types according to Absolute and Relative Spike Definitions

	Percent of Plants for Mach. Inv. Rate (Relative Spike Definition)	Percent of Plants for Bldg. Inv. Rate (Relative Spike Definition)	Percent of Plants for Mach. & Bldg. Inv. Rate (Relative Spike Definition)
Percent of Plants for Mach. Inv. Rate (Absolute Spike Definition)	0.902	0.966	0.932
Percent of Plants for Bldg. Inv. Rate (Absolute Spike Definition)	0.914	0.973	0.960
Percent of Plants for Mach. & Bldg. Inv. Rate (Absolute Spike Definition)	0.884	0.991	0.924

Table 13 presents the percentage of investment spike observations in each period for various investment types and definitions and shows that for all spike definitions and investment types, the first period, specifically the year 1973, has the highest fraction of investments over the 24-year sample.

Table 13. Percentage of Observations, which are Investment Spikes by periods for Possible Investment Types and Spike Definitions

	ABSOLUTE SPIKE DEFINITION			**RELATIVE SPIKE DEFINITION**		
Years in Periods	Fraction of Machinery Investment Spikes*	Fraction of Buildings Investment Spikes	Fraction of Machinery and Buildings Investment Spikes	Fraction of Machinery Investment Spikes	Fraction of Buildings Investment Spikes	Fraction of Machinery and Buildings Investment Spikes
1972-75	0.302	0.378	0.361	0.659	0.304	0.608
1976-80	0.264	0.267	0.281	0.178	0.276	0.206
1981-85	0.141	0.126	0.12	0.053	0.151	0.065
1986-90	0.163	0.133	0.138	0.065	0.15	0.075
1991-95	0.134	0.096	0.099	0.047	0.119	0.049

* Fraction of investment spikes based on various investment types is calculated as follows: i) the total number of investment spikes that occur from 1972 to 1995 is calculated; ii) the percentage of these spikes that occur in each year is calculated and period averages are reported.

Additional Table Notes: Percentage of observations which are investment spikes based on investment types and spike definitions are also represented for each year over the 24-year sample period in the Appendix, Table A.13 and figures 14-15.

There is a positive and significant correlation between fractions of various investment spikes across the two spike definitions during the specified time period (see Table 14).

Table 14. Correlation between Percentage of Observations, Which are Investment Spikes by Year for Investment Types according to Absolute and Relative Spike Definitions

	Fraction of Mach. Inv. Spikes (Relative Spike Definition)	Fraction of Bldg. Inv. Spikes (Relative Spike Definition)	Fraction of Mach. & Bldg. Inv. Spikes (Relative Spike Definition)
Fraction of Mach. Inv. Spikes (Absolute Spike Definition)	0.897	0.971	0.924
Fraction of Bldg. Inv. Spikes (Absolute Spike Definition)	0.938	0.983	0.960
Fraction of Mach. & Bldg. Inv. Spikes (Absolute Spike Definition)	0.906	0.983	0.934

VIII. Lumpy Investment and Productivity Growth

An initial investigation into the relationship between lumpy investment and TFP growth can draw on the results of Ericson and Pakes (1995) and Pakes and McGuire (1994). Ericson and Pakes (1995) build a model to illustrate how TFP growth rates relate to investment rates. In particular, both low and high TFP growth rates suggest periods of low investment. The high mortality rates of new firms are associated with an initial learning period where most perform poorly with low levels of investment after the initial startup costs. There is a threshold of TFP growth rates when firms decrease their investment after passing the threshold. Baumol and Wolfe (1983) arrive at similar results as they explore the feedback effects of R&D investment and productivity growth rates

The relationship between R&D and investment spikes cannot be empirically evaluated in this study. However, when R&D activity is associated with changes in how a firm undertakes its production activities such changes can involve significant additions and reorganizing of production processing and capacity which involves large changes in capital stock. Some of these changes may involve doing the same thing more extensively (i.e., extracting scale economies) and some of these changes may involve doing things differently (i.e., introducing new equipment and processes).[11] Initiatives to install additional capital may arise from a need to enhance productivity growth. However, productivity growth implies resource use decisions affecting the quantity of resources available for new production planning, in particular, and activities, in general. Thus, it is reasonable to consider the prospect that there is a simultaneous relationship between productivity growth and investment spikes. Investment spikes soon stimulate rapid growth of productivity in the sector when the spikes are associated with new technologies. But that, in turn, raises the price of investment in production capacity (and the productivity growth rate) and reduces the quantity of productive capacity demanded. In the following period productivity growth is impeded permitting a reduction in the productive capacity price stimulating demand for capacity-improving investment yet again.

While this conceptual model is highly simplified it does point out some dynamic disincentives of productive capacity investment. When productive capacity investment succeeds in increasing productivity growth, it automatically increases its own relative

[11] TFP can be decomposed into a scale effect and a technical change effect [as presented in (10)]. When an investment spike takes place, it can either expand the current plant using the same technology (a scale effect) or add new technology (the technical change effect). In the presence of decreasing returns to scale (which we find for all four TFP growth quartiles), the scale effect associated an increase in input use (capital in the case of an investment spike) leads to falling TFP. Finding a result where investment spikes lead to an increase in TFP growth implies the presence of some positive technical change. On the other hand, if investment spikes are negatively correlated with TFP growth, then the presence of decreasing returns to scale suggests the investment was not introducing new technology but rather increasing the scale of operations.

costs in comparison with production cost leading to a reduction in the financial incentive of this investment. Thus, the success of capacity-improving investment activity serves to undermine its own demand. Unfortunately, the more impressive the record of past success of capacity-improving investment activity the more strongly it tends to constrain private demand for productive capacity.

Given both the demand and supply side arguments regarding investment spikes and TFP growth rates, we investigate the impact of both impacts of investment spikes and TFP growth; namely, current investment spikes lead to higher future TFP growth rates, and higher current TFP growth rates impact the future investment spikes. We investigate two correlations. The first is the three-year average TFP growth rate centered on time t against the three-year average of the investment spikes centered on time t-2 (specifically, $TFP_{(t+1),t,(t-1)}$ vs. $IS_{(t-1),(t-2),(t-3)}$). The second is the three-year average TFP growth rate centered on time t-2 against the three-year average of the investment spikes centered on t (specifically, $TFP_{(t-1),(t-2),(t-3)}$ vs. $IS_{(t+1),t,(t-1)}$)[12]. We investigate these correlations considering various group of plants based on their TFP rankings, such as the lowest TFP ranked plants, middle ranged TFP ranked plants and the highest TFP ranked plants. Additionally, we have looked at the investment spikes considering two spike definitions (absolute and relative spikes) as well as different investment types (machinery, building and combined machinery and buildings).

Our correlation results show that correlation between the three-year average TFP growth rate centered on time t and the three-year average of the investment spikes

[12] We attempted two approaches to specify the three year average of investment spikes. The first approach takes the three year average of the investment spikes during those periods. The second approach considers investment spike as equal to 1 if there exist an investment spike in any of these periods, otherwise it is 0. Our results are fairly robust based on these two alternative characterizations of average investment spikes.

centered on time t-2 (specifically, $TFP_{(t+1),t,(t-1)}$ vs. $IS_{(t-1),(t-2),(t-3)}$) is high and positive for the middle ranged TFP ranked plants while there is no correlation for the lowest and the highest TFP ranked plants. This suggests strong evidence for the Ericson and Pakes prediction.

Turning to the demand for investment spikes, the correlation between the three-year average TFP growth rate centered on time t-2 and the three-year average of the investment spikes centred on t (specifically, $TFP_{(t-1),(t-2),(t-3)}$ vs. $IS_{(t+1),t,(t-1)}$) is positive and of moderate magnitude for the middle ranged TFP ranked plants and no correlation for the lowest and the highest ranked plants. This results hold for investment spike definitions, absolute and relative, and for all investment types, machinery, buildings and combined machinery and buildings. Therefore, for the middle ranked meat products manufacturing plants, investment spikes drive total factor productivity while there is no such an evidence for the highest and the lowest ranked meat manufacturing plants.

Pakes and McGuire (1994) find that investment can raise the probability of moving up in rankings. To investigate this issue, we look at the correlation between the change in TFP rankings and investment spikes for each plant by year. Our results do not show any significant correlation between the change in TFP rakings (plants' moving up in TFP rankings) and the investment spikes for the meat products industry.

IX. Conclusions

The findings from this study are:

i. In the TFP growth decomposition, the scale effect is the most significant component of the TFP growth for the plants, which are in the lowest rank throughout the time periods and in the highest rank except in the time period 1976-1980. The average contributions of scale effects to TFP growth for these ranks are 115.5% and 66%, respectively. The exogenous technical change effect presents the most significant contribution for the plants in the middle rank groups (rank 1 and rank 2), with an average of 133.7% and 85%, respectively. Plants that are in the lowest and the highest ranks extract scale efficiencies over technological progress. For the lowest ranked plants, this situation can suggest that these plants cannot afford to realize higher productivity growth through technological adoption but they have the potential to reorganize input allocations to achieve productivity growth.

ii. In the meat products sub-industry, exogenous input bias results show that, technical change is biased toward the capital input except in the 1981-1985 period and against the materials input except in the 1973-1975 period. For the energy input, technical change is biased toward the energy input after 1976-1980 and toward the labor input throughout the time periods.

iii. The time profile of productivity growth in the meat products sub-industry indicates that the plants, which are in rank 1 and rank 2 quartile groups, follow a similar pattern with an almost no gap between each other. However, the plants, which are in the highest ranked group (rank 3) and the lowest ranked group (rank 0) are exhibiting productivity pattern changes and maintaining the gap from other quartile groups. The lowest ranked plants catch the plants that are in ranks 1 and 2 after 1977 until 1984. They decrease the gap significantly when these plants are compared against the earlier years such as 1974, 1975 and 1976. Therefore, we detect various degrees of productivity between the meat products sub-industry plants and separate the productive plants from the relatively less productive plants throughout the time period. The results suggest that growth occurs for each productivity scale group even though the growth is negative for the lowest productive ranked group.

iv. In the analysis of the size effect of the productivity growth, plants that are in size categories B and D have the highest average productivity growth through the time period. The smallest size plants (size category A) present the most fluctuating productivity patterns compared to the larger sized plants. Therefore, this study finds that the smaller sized plants are more likely to fluctuate in their productivity rankings; in contrast, large plants are more stable in their productivity rankings. Investigation of the technical change contribution on TFP growth across plant sizes indicates that on average the smallest sized plants (size category A) have the highest technological change contribution on TFP growth in a same direction with TFP throughout the time periods.

v. The analysis investigating the number of times that plants change their productivity rankings shows that 9% of the meat products sub-industry plants do not change their productivity rankings throughout the time period. This percentage declines slightly as the plants get older and 25% of meat sub-industry plants switch once, while 18% of the youngest plants, 29% of the middle-aged plants and 26% of the oldest plants switch once. Considering all age categories and the industry plants pooled together for this sub-industry, 37% of all plants switching twice, 38% of the youngest plants, 33% of the middle-aged plants, and 38 % of the oldest plants throughout the time periods, suggesting considerable movement in plants' productivity categories for this industry.

vi. Plant productivity transition tables show that meat products sub-industry plants do not occupy a fixed rank with respect to their productivity levels. On the contrary, in no case do 50% of the plants stay in the same category, indicating considerable movement between productivity rank categories. Results from the transition tables based on age 1 category indicate that the youngest plants cannot sustain the highest rank (rank 3) and there exist considerable movement in their productivity rankings. The analysis of the plants which are in the age category 2, show that during the 1976-1981 time period, plants that are in ranks 0, 1 and 2 stay in their initial categories. However, for the rest of the time periods there exist considerable movement in productivity ranks except for the plants that are in rank 1 during the 1986-1991 time period. For the oldest plants, considerable movement across categories is observed and the less than half of the plants remain in the same category with most of the plants switching categories throughout the time periods.

vii. In the meat products sub-industry, each plant has already accounted for more than 70% of cumulative aggregate investment even in the first investment year (1972). Almost all plants (99%) in the meat products sub-industry have at least one year without a lumpy investment. As the industry presents considerable variation and frequent lumpy investment episodes dominating much of the investments, it continues to have non-lumpy ones.

viii. Investment analysis results strongly indicate that plant-level investments are quite lumpy since a relatively small percent of observations account for a disproportionate share of overall investment. A similar characteristic of investment spikes is seen across spike definitions and investment types in the meat products sub-industry. This finding is also clearly detected from annual contributions of the investment spikes to aggregate investments and the fraction of plants presenting lumpy investment episodes in each year. Therefore, both lumpy and non-lumpy investments are important components of investment for this industry.

ix. Initial investigation of the impacts of investment spikes and TFP growth; namely, current investment spikes lead to higher future TFP growth rates, and higher current TFP growth rates impact the future investment spikes show that investment spikes drive TFP for the middle ranked meat manufacturing plants, while there is no evidence for the highest and the lowest ranked meat manufacturing plants.

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APPENDIX

Table A. 1 Quadratic Production Function Estimation Using Fixed Effect Regression with 4-digit Industry Dummies for Meat Products Industry*

Variables	201 Sub-Industry
Constant	-
K	-1.19415 (-6.71)
L	6.02123 (3.35)
M	0.94607 (60.47)
E	-1.16099 (-0.52)
T	991.798 (3.89)
K^2	5.24e-06 (1.94)
KL	0.00007 (2.12)
KM	-1.35e-07 (-0.37)
KE	0.00003 (1.77)
L^2	-0.00069 (-1.31)
LM	3.02e-06 (1.02)
LE	0.00009 (0.77)
M^2	6.67e-08 (4.80)
ME	-0.00001 (-3.34)
E^2	-0.00012 (-3.44)
KT	0.08438 (10.20)
LT	0.08910 (1.05)
MT	0.00062 (0.95)
ET	0.29484 (2.76)
T^2	-86.29564 (-4.15)
R-squared	0.90
Hausman Specification Test χ^2	699.49 [0.0000]
Breusch and Pagan LM Test χ^2	1886.21 [0.0000]
N	4722

* T-statistics in parentheses, p-values in brackets

Table A.2 Average TFP Growth without Ranking Plants for every year in Meat Products Sub-Industry

Years	Mean TFP	Mean Scale	Mean Technical Change	Mean Returns to scale
1973	0.065374	0.02129	0.045259	0.93383
1974	0.099066	0.05983	0.039303	0.9004
1975	-0.07309	-0.11174	0.038835	0.9124
1976	0.023743	-0.00745	0.031363	0.86344
1977	0.024826	-0.00376	0.028615	0.9063
1978	0.031903	0.00518	0.027456	0.90057
1979	0.024451	0.00145	0.023148	0.87283
1980	0.020743	-0.00051	0.021257	0.89327
1981	0.014455	-0.00399	0.018446	0.89685
1982	0.019995	0.00337	0.016621	0.88796
1983	0.019227	0.00386	0.015372	0.89134
1984	-0.01829	-0.03201	0.013714	0.91073
1985	0.013674	0.00118	0.012498	0.90907
1986	0.013685	0.00111	0.012503	0.93856
1987	0.012141	0.00165	0.010436	0.94458
1988	0.008953	-0.00078	0.00973	0.95026
1989	0.005719	-0.00391	0.009615	0.96545
1990	0.009008	0.00192	0.007065	0.95276
1991	0.004921	-0.00134	0.006253	0.99765
1992	0.01253	0.00769	0.004866	1.00923
1993	0.016489	0.01227	0.004144	1.00497
1994	-0.01329	-0.01594	0.002575	1.01402
1995	0.001559	0.00339	-0.00189	0.97605

Table A. 3a TFP Decomposition for Rank 0 in each year

Years	TFP Growth	Scale Effect	Technical Change Effect	Average Returns to Scale
1973	-0.00705	-0.03108	0.024028	0.91301
1974	-0.04287	-0.06239	0.019521	0.86019
1975	-0.4686	-0.48774	0.019142	0.88889
1976	-0.03459	-0.05394	0.019348	0.80166
1977	-0.02559	-0.04385	0.018259	0.85231
1978	-0.00117	-0.017	0.015828	0.85706
1979	-0.01282	-0.03143	0.018605	0.84058
1980	-0.01847	-0.0335	0.015028	0.84783
1981	-0.01687	-0.02984	0.012973	0.80487
1982	-0.01703	-0.02926	0.012234	0.85684
1983	-0.01913	-0.03152	0.012393	0.87473
1984	-0.15247	-0.16059	0.008126	0.91847
1985	-0.0446	-0.05229	0.00769	0.78861
1986	-0.04658	-0.05513	0.008543	0.92054
1987	-0.03424	-0.04352	0.009278	0.87303
1988	-0.04148	-0.05068	0.009209	0.93212
1989	-0.05962	-0.06806	0.008436	0.98
1990	-0.03408	-0.03384	-0.00024	0.90606
1991	-0.0432	-0.04342	0.000224	0.92899
1992	-0.03105	-0.02831	-0.00274	0.97646
1993	-0.02959	-0.02672	-0.00288	0.97202
1994	-0.08936	-0.08417	-0.00518	0.96739
1995	-0.06733	-0.04679	-0.02054	0.9978

Table A. 3b TFP Decomposition for Rank 1 in each year

Years	TFP Growth	Scale Effect	Technical Change Effect	Average Returns to Scale
1973	0.034647	0.003377	0.03127	0.94595
1974	0.017997	-0.00413	0.022128	0.92393
1975	0.024761	-0.00529	0.030056	0.95828
1976	0.00812	-0.0083	0.016423	0.90424
1977	0.015294	-0.0045	0.019797	0.9217
1978	0.021986	0.002246	0.01974	0.92327
1979	0.016215	-0.00376	0.019971	0.88258
1980	0.011144	-0.00758	0.018724	0.87955
1981	0.005989	-0.00783	0.013818	0.90188
1982	0.009873	-0.00259	0.01246	0.91473
1983	0.007233	-0.00385	0.01108	0.90064
1984	0.007862	-0.00166	0.009526	0.93575
1985	0.00335	-0.00465	0.008001	0.93858
1986	0.005449	-0.00146	0.006913	0.95592
1987	0.002756	-0.00299	0.00575	0.92107
1988	0.004556	-0.00044	0.004995	0.96126
1989	0.004223	-0.00089	0.005117	0.95708
1990	0.00071	-0.00378	0.004489	0.95336
1991	0.002104	-0.00216	0.004261	0.97047
1992	0.002443	-0.00128	0.003723	0.96822
1993	0.001259	-0.00191	0.003174	0.97897
1994	-0.00267	-0.00458	0.001912	0.95818
1995	-0.00181	-0.0018	-1.5E-05	0.97525

Table A. 3c TFP Decomposition for Rank 2 in each year

Years	TFP Growth	Scale Effect	Technical Change Effect	Average Returns to Scale
1973	0.056158	0.009032	0.047126	0.97326
1974	0.048318	0.002746	0.045571	0.97229
1975	0.04578	0.006852	0.038928	0.91515
1976	0.028635	-0.00396	0.032591	0.89602
1977	0.03167	0.00314	0.02853	0.94624
1978	0.033844	0.004922	0.028922	0.93419
1979	0.029244	0.005632	0.023613	0.89169
1980	0.023993	0.002177	0.021816	0.94393
1981	0.018135	0.000734	0.017401	0.93441
1982	0.019638	0.002976	0.016663	0.91744
1983	0.018342	0.003924	0.014418	0.90231
1984	0.01789	0.003409	0.014481	0.90564
1985	0.01527	0.001694	0.013576	0.94192
1986	0.015658	0.002825	0.012833	0.92538
1987	0.015189	0.004474	0.010716	0.96787
1988	0.015106	0.004641	0.010465	0.95892
1989	0.013512	0.002584	0.010928	0.96882
1990	0.010821	0.001507	0.009315	0.9598
1991	0.010519	0.00262	0.007899	0.98529
1992	0.011066	0.003622	0.007444	1.03652
1993	0.011514	0.003483	0.00803	1.00762
1994	0.007231	0.004066	0.003165	1.02387
1995	0.008764	0.003893	0.004871	0.94478

Table A. 3d TFP Decomposition for Rank 3 in each year

Years	TFP Growth	Scale Effect	Technical Change Effect	Average Returns to Scale
1973	0.17623	0.10275	0.073484	0.90335
1974	0.37557	0.30563	0.069933	0.85037
1975	0.09745	0.03141	0.066045	0.89431
1976	0.09159	0.03543	0.056164	0.8556
1977	0.07691	0.02936	0.04755	0.90434
1978	0.07312	0.03063	0.042496	0.89825
1979	0.06507	0.03527	0.029803	0.8767
1980	0.06631	0.03685	0.029461	0.90178
1981	0.05049	0.02088	0.029613	0.94549
1982	0.06771	0.0425	0.025213	0.86167
1983	0.07072	0.04702	0.023704	0.88728
1984	0.05281	0.0301	0.022706	0.88317
1985	0.08064	0.05994	0.020702	0.9665
1986	0.08021	0.0582	0.022018	0.95791
1987	0.06479	0.04859	0.016203	1.02412
1988	0.05662	0.04237	0.014243	0.94839
1989	0.06463	0.05053	0.014102	0.95132
1990	0.05855	0.04382	0.014728	0.99616
1991	0.05015	0.03752	0.012629	1.09694
1992	0.0679	0.05699	0.01091	1.05312
1993	0.08319	0.07469	0.0085	1.06206
1994	0.03101	0.02029	0.010718	1.10875
1995	0.06661	0.05825	0.008358	0.99817

Table A. 4 Exogenous Input Bias for each year

Years	Capital Input	Labor Input	Material Input	Energy Input
1973	12.1842	0.10952	0.080868	-0.14694
1974	1.6369	0.07976	0.04494	-0.32702
1975	0.6454	-0.06291	-0.0663	-0.56416
1976	0.17	-0.00356	-0.00932	-2.31784
1977	0.0465	0.04367	0.012887	1.2382
1978	0.1833	0.0382	-0.00832	0.44555
1979	-0.1106	0.03392	-0.01588	0.0914
1980	-0.0087	-0.00991	-0.01194	0.31289
1981	-0.3872	-0.0384	-0.00444	0.16902
1982	-0.5059	-0.00784	-0.01733	0.09511
1983	-0.6075	0.06282	-0.025	0.35104
1984	-0.8978	0.04312	-0.0273	0.19073
1985	-0.3197	0.00877	0.002873	0.33453
1986	1.4314	0.11528	-0.04159	0.12804
1987	0.492	-0.02528	0.017458	-0.03618
1988	0.4236	0.07784	-0.01716	0.31799
1989	0.3992	0.0241	0.024612	-0.02972
1990	0.2237	0.04574	-0.0051	0.0861
1991	0.1771	-0.01034	-0.00557	-0.25552
1992	0.1616	-0.00502	0.041713	0.10725
1993	0.1748	0.0397	-0.03067	0.2122
1994	0.1281	0.00331	0.002991	0.04542
1995	0.2563	0.03401	-0.04467	0.05709

A.5 Direct Size Effect on TFP growth Decomposition (Tables A.5a-A.5d)

Table A. 5a SIZE CATEGORY A (The smallest size category)

Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	-0.0028	-0.0494	0.0476	0.8664
1976-1980	0.0254	-0.0022	0.0276	0.8302
1981-1985	-0.0143	-0.0279	0.0136	0.8857
1986-1990	0.0021	-0.0023	0.0043	0.9091
1991-1995	-0.0076	0.0020	-0.0095	0.9823
1973-1995	0.00084	-0.0672	0.00901	0.8939

Table A. 5b SIZE CATEGORY B (Middle Size category)

Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0524	0.0018	0.0509	0.9262
1976-1980	0.0302	-0.0006	0.0309	0.8943
1981-1985	0.0163	-0.0003	0.0166	0.8909
1986-1990	0.0111	0.0027	0.0083	0.9255
1991-1995	0.0092	0.0055	0.0036	0.9979
1973-1995	0.0213	-0.0030	0.0119	0.9361

Table A. 5c SIZE CATEGORY C (Middle-Larger size category)

Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0431	0.0022	0.0412	0.9611
1976-1980	0.0267	-0.0007	0.0280	0.9196
1981-1985	0.0178	0.0034	0.0144	0.9056
1986-1990	0.0117	0.0004	0.0113	0.9635
1991-1995	0.0123	0.0037	0.0086	1.0335
1973-1995	0.0205	0.0034	0.0187	0.9502

Table A. 5d SIZE CATEGORY D (The Largest Size Category)

Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0314	0.0065	0.0249	0.9078
1976-1980	0.0183	-0.0006	0.0190	0.9047
1981-1985	0.0194	0.0026	0.0167	0.9145
1986-1990	0.0147	-0.0008	0.0155	1.0026
1991-1995	0.0035	-0.0065	0.0097	0.9877
1973-1995	0.0162	0.0565	0.0291	0.9490

A.6 Secondary Decomposition of TFP Growth based on Size Categories

(Tables A.6a-4.A.6d)

Table A. 6a TFP RANK 0

SIZE CATEGORY A				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	-0.7034	-0.7346	0.0311	0.8144
1976-1980	-0.0285	-0.0461	0.0177	0.7953
1981-1985	-0.1469	-0.1542	0.0073	0.8878
1986-1990	-0.0492	-0.0440	-0.0052	0.8626
1991-1995	-0.0628	-0.0305	-0.0323	0.9463
1973-1995	-0.1542	-0.1556	0.0013	0.8654
SIZE CATEGORY B				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	-0.0275	-0.0513	0.0237	0.9020
1976-1980	-0.0173	-0.0386	0.0213	0.7978
1981-1985	-0.0272	-0.0403	0.0130	0.8198
1986-1990	-0.0289	-0.0364	0.0075	0.8809
1991-1995	-0.0278	-0.0234	-0.0044	1.0238
1973-1995	-0.0256	-0.0368	0.0112	0.8834
SIZE CATEGORY C				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	-0.0036	-0.0215	0.0179	0.9105
1976-1980	-0.0136	-0.0309	0.0173	0.8712
1981-1985	-0.0152	-0.0277	0.0125	0.8424
1986-1990	-0.0410	-0.0480	0.0071	0.9080
1991-1995	-0.0246	-0.0252	0.0007	0.9082
1973-1995	-0.0210	-0.0315	0.0105	0.8861
SIZE CATEGORY D				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0008	-0.0106	0.0114	0.9170
1976-1980	-0.0154	-0.0289	0.0134	0.8936
1981-1985	-0.0136	-0.0234	0.0098	0.8454
1986-1990	-0.0540	-0.0728	0.0188	1.0391
1991-1995	-0.0955	-0.1061	0.0105	1.0009
1973-1995	-0.0387	-0.0516	0.0129	0.9411

Table A. 6b TFP RANK 1

SIZE CATEGORY A				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0230	-0.0032	0.0262	0.9178
1976-1980	0.0137	-0.0044	0.0181	0.8780
1981-1985	0.0059	-0.0024	0.0083	0.9205
1986-1990	0.0028	0.0013	0.0015	0.9339
1991-1995	-0.0010	-0.0008	-0.0002	0.9838
1973-1995	0.00764	-0.0018	0.0094	0.9276
SIZE CATEGORY B				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0279	-0.0053	0.0331	0.9434
1976-1980	0.0156	-0.0068	0.0224	0.9117
1981-1985	0.0077	-0.0053	0.0130	0.9068
1986-1990	0.0039	-0.0019	0.0058	0.9641
1991-1995	0.0005	-0.0032	0.0008	0.9606
1973-1995	0.0097	-0.0038	0.0135	0.9368
SIZE CATEGORY C				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0264	-0.0053	0.0316	0.9857
1976-1980	0.0145	-0.0046	0.0191	0.9109
1981-1985	0.0068	-0.0054	0.0122	0.9295
1986-1990	0.0037	-0.0039	0.0075	0.9546
1991-1995	0.0008	-0.0035	0.0043	0.9841
1973-1995	0.0090	-0.0045	0.0135	0.9501
SIZE CATEGORY D				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0260	0.0057	0.0203	0.9234
1976-1980	0.0145	-0.0018	0.0163	0.9082
1981-1985	0.0071	-0.0032	0.0102	0.9160
1986-1990	0.0038	-0.0029	0.0068	0.9454
1991-1995	0.0006	-0.0048	0.0054	0.9513
1973-1995	0.0091	-0.002	0.0110	0.9293

Table A. 6c TFP RANK 2

SIZE CATEGORY A				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0497	0.0061	0.0436	0.9318
1976-1980	0.0305	0.0017	0.0288	0.8955
1981-1985	0.0181	0.0034	0.0147	0.8930
1986-1990	0.0135	0.0041	0.0094	0.9252
1991-1995	0.0096	0.0079	0.0016	0.9692
1973-1995	0.0221	0.0045	0.0175	0.9222
SIZE CATEGORY B				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0506	0.0057	0.0449	0.9743
1976-1980	0.0294	0.0008	0.0286	0.9349
1981-1985	0.0182	0.0013	0.0168	0.9269
1986-1990	0.0140	0.0035	0.0105	0.9681
1991-1995	0.0094	0.0029	0.0065	1.039
1973-1995	0.0220	0.0026	0.0194	0.9681
SIZE CATEGORY C				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0504	0.0050	0.0454	0.9900
1976-1980	0.0297	0.0010	0.0287	0.9403
1981-1985	0.0174	0.0025	0.0148	0.9351
1986-1990	0.0145	0.0027	0.0117	0.9601
1991-1995	0.0100	0.0022	0.0078	0.9929
1973-1995	0.0221	0.0025	0.0196	0.9614
SIZE CATEGORY D				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0496	0.0081	0.0415	0.9162
1976-1980	0.0283	0.0062	0.0221	0.9178
1981-1985	0.0178	0.0030	0.0148	0.9246
1986-1990	0.0143	0.0025	0.0117	0.9690
1991-1995	0.0104	0.0014	0.0090	0.9962
1973-1995	0.0218	0.0039	0.0179	0.9472

Table A. 6d TFP RANK 3

SIZE CATEGORY A				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.1942	0.1121	0.0821	0.8500
1976-1980	0.0768	0.0332	0.0436	0.8280
1981-1985	0.0759	0.0524	0.0235	0.8577
1986-1990	0.0678	0.0542	0.0136	0.9179
1991-1995	0.0695	0.0667	0.0028	1.0170
1973-1995	0.0884	0.0595	0.0289	0.8980
SIZE CATEGORY B				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.4643	0.3830	0.0813	0.9232
1976-1980	0.0711	0.0345	0.0366	0.8482
1981-1985	0.0546	0.0324	0.0222	0.8885
1986-1990	0.0594	0.0463	0.0131	0.9406
1991-1995	0.0598	0.0486	0.0112	1.1628
1973-1995	0.1138	0.0851	0.0287	0.9552
SIZE CATEGORY C				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.0966	0.0397	0.0569	0.8737
1976-1980	0.0698	0.0265	0.0433	0.9538
1981-1985	0.0592	0.0394	0.0198	0.9168
1986-1990	0.0589	0.0429	0.0161	1.0186
1991-1995	0.0559	0.0441	0.0118	1.0065
1973-1995	0.0656	0.0384	0.0272	0.9608
SIZE CATEGORY D				
Time Period	Mean TFP	Mean Scale	Mean Technical Change	Average Returns to Scale
1973-1975	0.1105	0.0516	0.0589	0.8838
1976-1980	0.0807	0.0399	0.0408	0.9181
1981-1985	0.0687	0.0363	0.0325	0.9717
1986-1990	0.0741	0.0516	0.0224	1.0233
1991-1995	0.0541	0.0393	0.0149	1.0738
1973-1995	0.0748	0.0430	0.0317	0.9820

Table A.7 Plants' Productivity Transitions between Categories across Time Periods

		1981			
		Rank 0	**Rank 1**	**Rank 2**	**Rank 3**
1976	**Rank 0**	0.47	0.24	0.18	0.11
	Rank 1	0.27	0.33	0.17	0.23
	Rank 2	0.08	0.25	0.44	0.23
	Rank 3	0.19	0.19	0.23	0.39

		1986			
		Rank 0	**Rank 1**	**Rank 2**	**Rank 3**
1981	**Rank 0**	0.40	0.32	0.13	0.15
	Rank 1	0.27	0.35	0.18	0.20
	Rank 2	0.19	0.19	0.33	0.29
	Rank 3	0.17	0.15	0.32	0.34

		1991			
		Rank 0	**Rank 1**	**Rank 2**	**Rank 3**
1986	**Rank 0**	0.31	0.20	0.29	0.20
	Rank 1	0.33	0.35	0.15	0.17
	Rank 2	0.17	0.33	0.30	0.20
	Rank 3	0.15	0.13	0.26	0.45

Table A.8 Plants' Productivity Transitions between Categories across Time Periods based on Age Category 1

1976 \ 1981	Rank 0	Rank 1	Rank 2	Rank 3
Rank 0	0.8	0.2	0	0
Rank 1	0.36	0.36	0.18	0.09
Rank 2	0	0.45	0.36	0.18
Rank 3	0.27	0.43	0	0.14

1981 \ 1986	Rank 0	Rank 1	Rank 2	Rank 3
Rank 0	0.37	0.18	0.09	0.09
Rank 1	0.21	0.43	0.21	0.14
Rank 2	0	0.5	0.33	0.17
Rank 3	0.2	0.4	0.4	0

1986 \ 1991	Rank 0	Rank 1	Rank 2	Rank 3
Rank 0	0.36	0.18	0.18	0.27
Rank 1	0.46	0.23	0.23	0.08
Rank 2	0.38	0.5	0.12	0
Rank 3	0.25	0	0.5	0.25

Table A.9 Plants' Productivity Transitions between Categories across Time Periods based on Age Category 2

1976 → 1981	Rank 0	Rank 1	Rank 2	Rank 3
Rank 0	0.67	0.33	0	0
Rank 1	0	0.72	0.14	0.14
Rank 2	0.14	0.29	0.57	0
Rank 3	0	0.5	0.25	0.25

1981 → 1986	Rank 0	Rank 1	Rank 2	Rank 3
Rank 0	0	0.67	0	0.33
Rank 1	0.5	0.2	0	0.3
Rank 2	0.33	0.17	0.17	0.33
Rank 3	0.5	0	0	0.5

1986 → 1991	Rank 0	Rank 1	Rank 2	Rank 3
Rank 0	0.37	0	0.63	0
Rank 1	0.2	0.6	0.2	0
Rank 2	1	0	0	0
Rank 3	0.14	0	0.43	0.43

Table A.10 Plants' Productivity Transitions between Categories across Time Periods based on Age Category 3

1976 → 1981	Rank 0	Rank 1	Rank 2	Rank 3
Rank 0	0.41	0.24	0.22	0.13
Rank 1	0.3	0.23	0.17	0.3
Rank 2	0.1	0.17	0.43	0.3
Rank 3	0.16	0.11	0.27	0.46

1981 → 1986	Rank 0	Rank 1	Rank 2	Rank 3
Rank 0	0.37	0.33	0.15	0.15
Rank 1	0.2	0.36	0.24	0.2
Rank 2	0.19	0.14	0.36	0.31
Rank 3	0.15	0.13	0.33	0.38

1986 → 1991	Rank 0	Rank 1	Rank 2	Rank 3
Rank 0	0.27	0.27	0.23	0.23
Rank 1	0.3	0.37	0.1	0.23
Rank 2	0.11	0.30	0.35	0.24
Rank 3	0.14	0.17	0.19	0.47

Table A.11 Time Series Contributions of Investment Spikes to Aggregate Investments based on Investment Types and Spike Definitions

	Absolute Spike Definition						Relative Spike Definition					
Years	Percent of Plants having Mach. Inv. Spikes	Percent of Total Inv. accounted for by Mach. Inv. Spikes	Percent of Plants having Bldg. Inv. Spikes	Percent of Total Inv. accounted for by Bldg. Inv. Spikes	Percent of Plants having Mach. &Bldg. Inv. Spikes	Percent of Total Inv. accounted for by Mach. & Bldg. Inv. Spikes	Percent of Plants having Mach. Inv. Spikes	Percent of Total Inv. accounted for by Mach. Inv. Spikes	Percent of Plants having Bldg. Inv. Spikes	Percent of Total Inv. accounted for by Bldg. Inv. Spikes	Percent of Plants having Mach. &Bldg. Inv. Spikes	Percent of Total Inv. accounted for by Mach.& Bldg. Inv. Spikes
72	0.86	1.00	0.67	1.00	0.88	1.00	0.85	1.00	0.68	1.00	0.86	1.00
73	0.90	1.00	0.67	1.00	0.91	1.00	0.89	0.99	0.67	1.00	0.91	1.00
74	0.78	0.98	0.59	0.97	0.81	0.98	0.59	0.84	0.64	0.99	0.67	0.89
75	0.68	0.93	0.41	0.91	0.67	0.92	0.32	0.60	0.47	0.96	0.38	0.68
76	0.59	0.88	0.39	0.88	0.55	0.83	0.21	0.47	0.48	0.94	0.24	0.51
77	0.66	0.91	0.35	0.85	0.61	0.88	0.24	0.46	0.46	0.93	0.27	0.54
78	0.59	0.86	0.36	0.84	0.55	0.84	0.13	0.31	0.48	0.94	0.22	0.46
79	0.57	0.82	0.31	0.77	0.49	0.75	0.08	0.20	0.44	0.89	0.13	0.29
80	0.42	0.72	0.23	0.71	0.35	0.66	0.06	0.18	0.37	0.87	0.10	0.29
81	0.31	0.63	0.22	0.72	0.29	0.62	0.05	0.18	0.34	0.87	0.07	0.26
82	0.27	0.56	0.12	0.57	0.18	0.46	0.02	0.10	0.21	0.75	0.04	0.18
83	0.31	0.65	0.17	0.70	0.23	0.56	0.04	0.17	0.26	0.83	0.07	0.26
84	0.27	0.57	0.11	0.61	0.15	0.40	0.03	0.14	0.16	0.71	0.03	0.16
85	0.35	0.67	0.15	0.62	0.24	0.57	0.06	0.20	0.25	0.77	0.08	0.28
86	0.37	0.70	0.18	0.73	0.28	0.64	0.06	0.22	0.25	0.83	0.09	0.31
87	0.32	0.60	0.12	0.59	0.23	0.52	0.04	0.16	0.19	0.72	0.05	0.19
88	0.33	0.61	0.17	0.65	0.25	0.55	0.04	0.12	0.26	0.80	0.06	0.21
89	0.41	0.70	0.21	0.71	0.30	0.62	0.06	0.20	0.27	0.81	0.09	0.29
90	0.31	0.59	0.15	0.62	0.20	0.48	0.05	0.16	0.23	0.77	0.05	0.18
91	0.27	0.58	0.11	0.57	0.17	0.48	0.07	0.26	0.20	0.75	0.06	0.24
92	0.28	0.59	0.14	0.64	0.20	0.51	0.04	0.15	0.21	0.78	0.05	0.21
93	0.28	0.57	0.10	0.55	0.17	0.43	0.02	0.10	0.17	0.70	0.03	0.14
94	0.23	0.47	0.09	0.48	0.15	0.39	0.01	0.07	0.18	0.66	0.03	0.13
95	0.35	0.64	0.15	0.64	0.22	0.52	0.03	0.12	0.21	0.75	0.05	0.20
Mean	0.45	0.72	0.26	0.72	0.38	0.65	0.17	0.31	0.34	0.83	0.19	0.37

Table A.12a Correlation between Aggregated Investment Rate and Fraction of Plants with Spiky Investment Rate according to Spike Definitions

	ABSOLUTE SPIKE DEFINITION			RELATIVE SPIKE DEFINITION		
	Aggregate Mach. Inv. Rate	Aggregate Bldg. Inv. Rate	Aggregate Mach. & Bldg. Inv. Rate	Aggregate Mach. Inv. Rate	Aggregate Bldg. Inv. Rate	Aggregate Mach. & Bldg. Inv. Rate
Fraction of Plants with Spiky Mach. Inv. Rate	0.4738	0.4729	0.4779	0.6190	0.6167	0.6231
Fraction of Plants with Spiky Bldg. Inv. Rate	0.5319	0.5315	0.5362	0.4807	0.4812	0.4851
Fraction of Plants with Spiky Mach.& Bldg. Inv. Rate	0.4780	0.4774	0.4805	0.5913	0.5893	0.5955

Table A.12b Correlation between Aggregated Investment Rate and Investment Accounted by the plants that have spiky investments according to Spike Definitions

	ABSOLUTE SPIKE DEFINITION			RELATIVE SPIKE DEFINITION		
	Aggregate Mach. Inv. Rate	Aggregate Bldg. Inv. Rate	Aggregate Mach. & Bldg. Inv. Rate	Aggregate Mach. Inv. Rate	Aggregate Bldg. Inv. Rate	Aggregate Mach. & Bldg. Inv. Rate
Mach. Inv. Accounted by Lumpy Inv. Plants	0.4134	0.4133	0.4173	0.5691	0.5673	0.5731
Bldg. Inv. Accounted by Lumpy Inv. Plants	0.4322	0.4326	0.4362	0.3795	0.3809	0.3836
Mach. & Bldg. Inv. Accounted by Lumpy Inv. Plants	0.4104	0.4107	0.4144	0.5435	0.5422	0.5477

Table A.13 Percentage of Observations, which are Investment Spikes by Year for Possible Investment Types and Spike Definitions

ABSOLUTE SPIKE DEFINITION				RELATIVE SPIKE DEFINITION		
Years	Fraction of Machinery Investment Spikes	Fraction of Buildings Investment Spikes	Fraction of Machinery and Buildings Investment Spikes	Fraction of Machinery Investment Spikes	Fraction of Buildings Investment Spikes	Fraction of Machinery and Buildings Investment Spikes
1972	0.081	0.108	0.097	0.212	0.084	0.185
1973	0.084	0.108	0.101	0.22	0.083	0.196
1974	0.073	0.096	0.089	0.147	0.079	0.144
1975	0.064	0.066	0.074	0.08	0.058	0.083
1976	0.055	0.064	0.061	0.051	0.059	0.051
1977	0.062	0.057	0.067	0.058	0.057	0.059
1978	0.055	0.058	0.061	0.033	0.06	0.047
1979	0.053	0.051	0.054	0.021	0.054	0.028
1980	0.039	0.037	0.038	0.015	0.046	0.021
1981	0.029	0.036	0.032	0.012	0.042	0.016
1982	0.025	0.019	0.02	0.006	0.026	0.01
1983	0.029	0.028	0.025	0.011	0.032	0.015
1984	0.025	0.018	0.016	0.009	0.02	0.007
1985	0.033	0.025	0.027	0.015	0.031	0.017
1986	0.035	0.029	0.031	0.016	0.031	0.02
1987	0.03	0.019	0.025	0.011	0.024	0.011
1988	0.031	0.028	0.027	0.01	0.033	0.014
1989	0.038	0.033	0.033	0.016	0.034	0.019
1990	0.029	0.024	0.022	0.012	0.028	0.011
1991	0.025	0.018	0.018	0.018	0.024	0.013
1992	0.027	0.023	0.022	0.01	0.026	0.012
1993	0.027	0.016	0.019	0.006	0.021	0.006
1994	0.022	0.014	0.016	0.004	0.022	0.006
1995	0.033	0.025	0.024	0.009	0.026	0.012

Figure 1. Average TFP Growth in Meat Products Sub-Industry

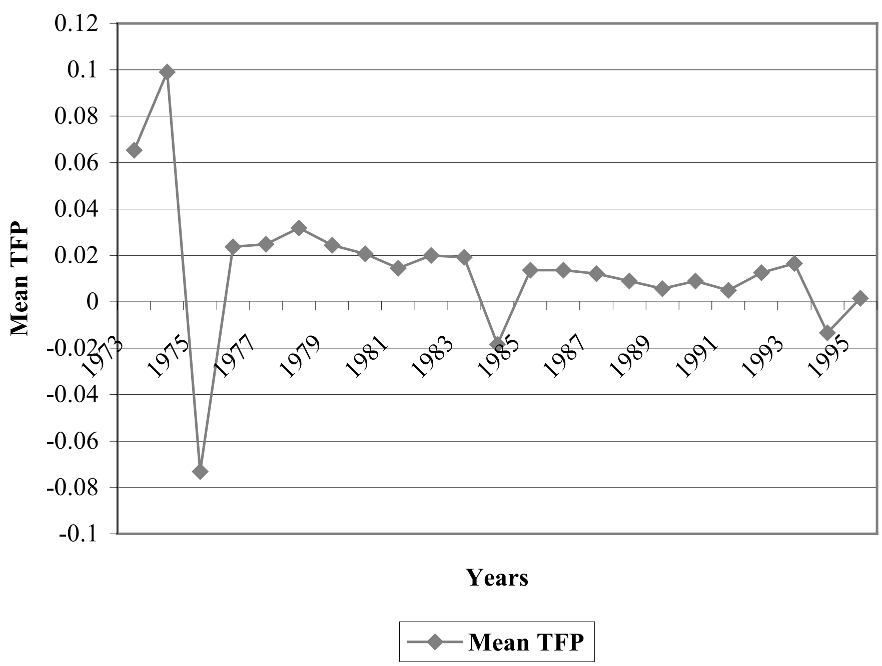


Figure 2. Mean Residuals in Meat Products Sub-Industry

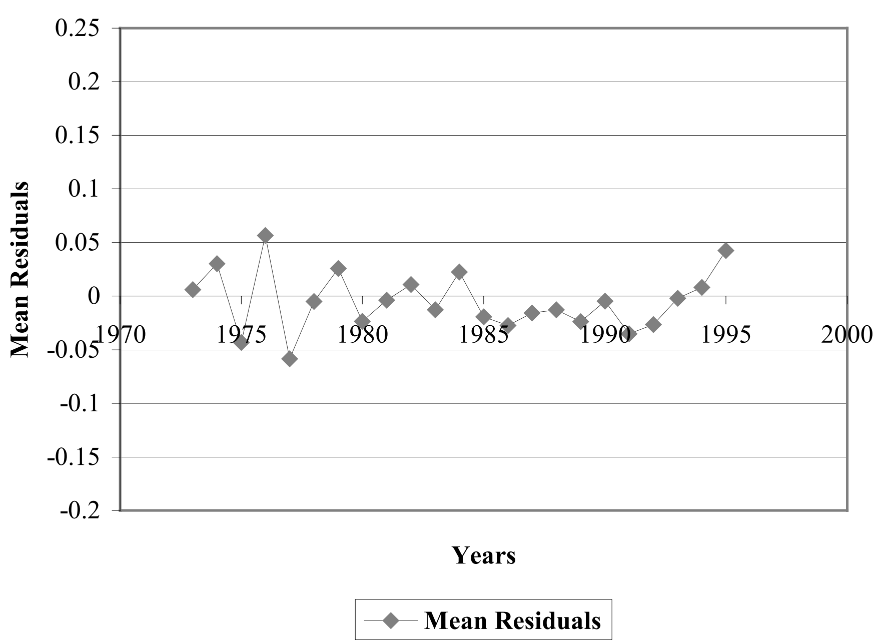


Figure 3. All Ranked TFP Together in Meat Products Sub-Industry

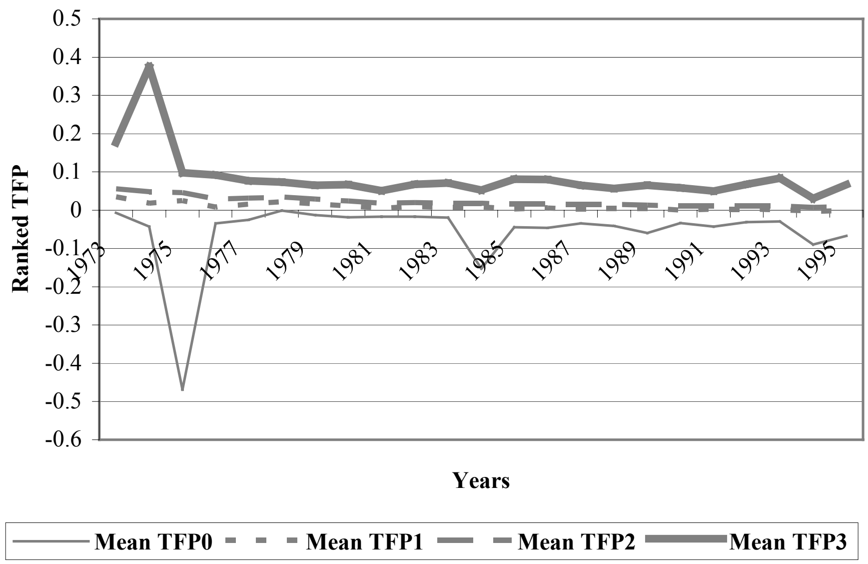
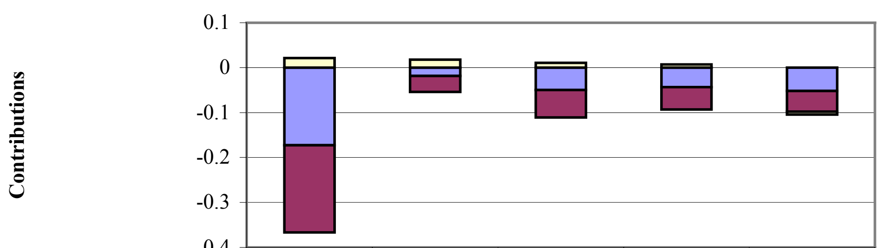


Figure 4. TFP, Scale and Technical Change Effects in Meat Products Sub-Industry for Rank 0

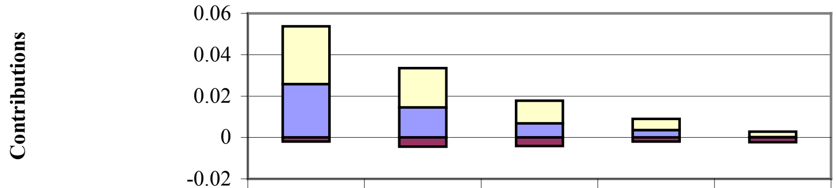


	1973-1975	1976-1980	1981-1985	1986-1990	1991-1995
Mean Tech. Change	0.020897	0.017414	0.010683	0.007044	-0.006223
Mean Scale	-0.19374	-0.03594	-0.0607	-0.05024	-0.04588
Mean TFP	-0.17284	-0.01853	-0.05002	-0.0432	-0.05211

Time Periods

Mean TFP **Mean Scale** **Mean Tech. Change**

Figure 5. TFP, Scale and Technical Change Effects in Meat Products Sub-Industry for Rank 1

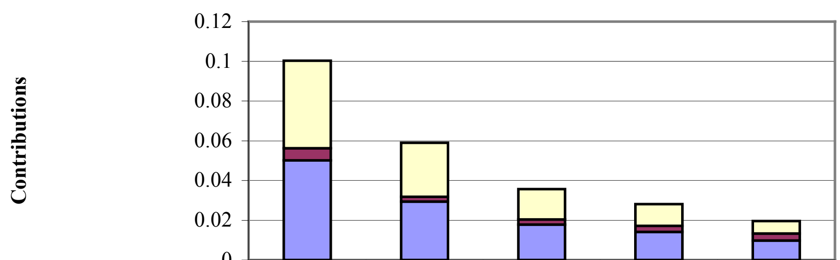


	1973-1975	1976-1980	1981-1985	1986-1990	1991-1995
Mean Tech. Change	0.027818	0.018931	0.010977	0.005453	0.002611
Mean Scale	-0.00201612	-0.00437937	-0.00411555	-0.0019137	-0.00234619
Mean TFP	0.025802	0.014552	0.006862	0.003539	0.000265

Time Periods

Mean TFP **Mean Scale** **Mean Tech. Change**

Figure 6. TFP, Scale and Technical Change Effects in Meat Products Sub-Industry for Rank 2

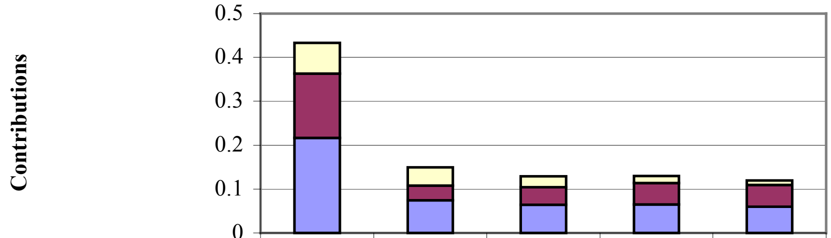


	1973-1975	1976-1980	1981-1985	1986-1990	1991-1995
Mean Tech. Change	0.043875	0.027094	0.015308	0.010851	0.006282
Mean Scale	0.00621021	0.00238316	0.0025472	0.00320592	0.00353697
Mean TFP	0.050085	0.029477	0.017855	0.014057	0.009819

Time Periods

Mean TFP **Mean Scale** **Mean Tech. Change**

Figure 7. TFP, Scale and Technical Change Effects in Meat Products Sub-Industry for Rank 3

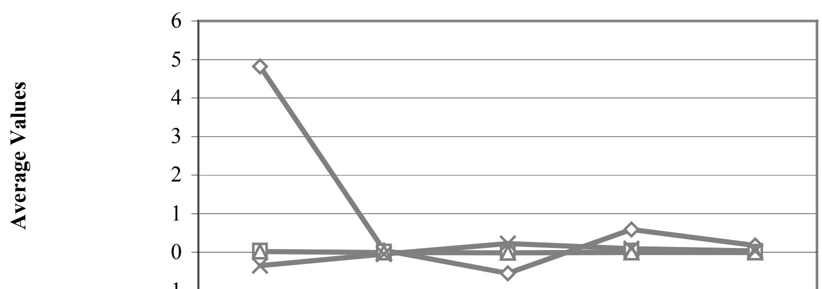


	1973-1975	1976-1980	1981-1985	1986-1990	1991-1995
Mean Tech. Change	0.069821	0.041095	0.024388	0.016259	0.010223
Mean Scale	0.1466	0.0335	0.04009	0.0487	0.04955
Mean TFP	0.21642	0.0746	0.06448	0.06496	0.05977

Time Periods

Mean TFP **Mean Scale** **Mean Tech. Change**

Figure 8. Average Input Bias for Meat Products Sub-Industry



	1973-1975	1976-1980	1981-1985	1986-1990	1991-1995
Capital	4.82216	0.0561	-0.54361	0.59399	0.17958
Labor	0.042124	0.020463	0.013696	0.047537	0.012331
Materials	0.019836	-0.006513	-0.014239	-0.004355	-0.00724
Energy	-0.34604	-0.04596	0.22809	0.09325	0.03329

Time Periods

Capital **Labor** **Materials** **Energy**

Figure 9. Investment Rate vs. Machinery Investment Spikes for Meat Products Sub-Industry

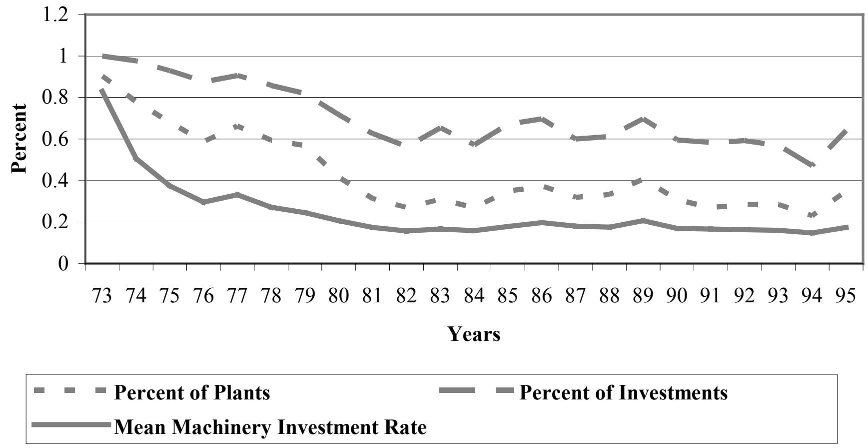


Figure 10. Investments Rate vs. Building Investment Spikes for Meat Products Sub-Industry

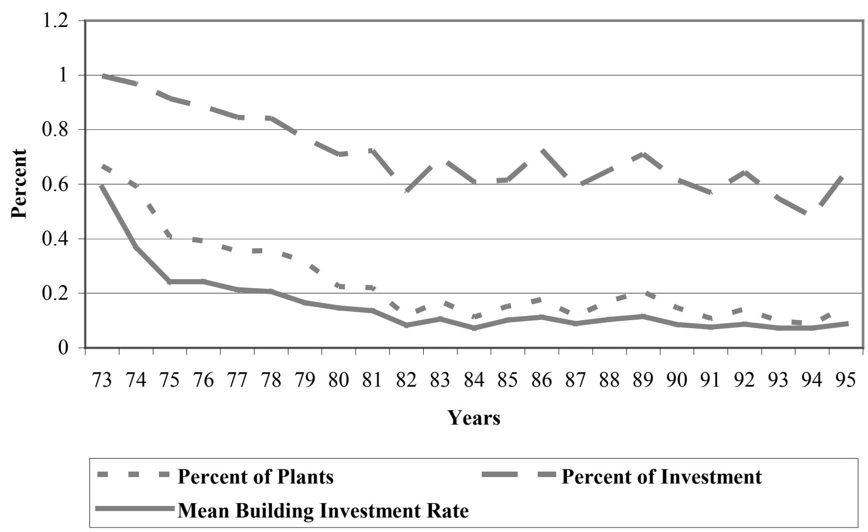


Figure 11. Investment Rates vs. Machinery and Building Investment Spikes for Meat Products Sub-Industry

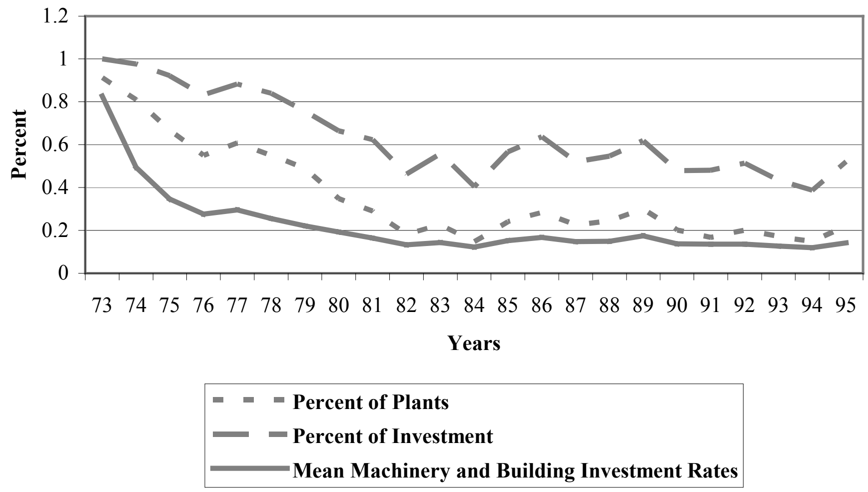
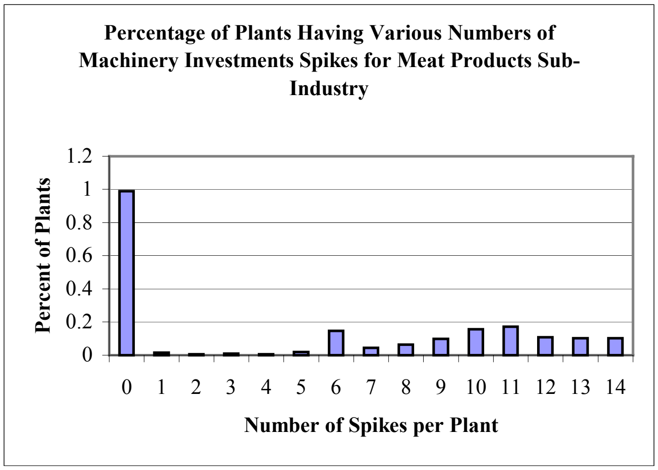
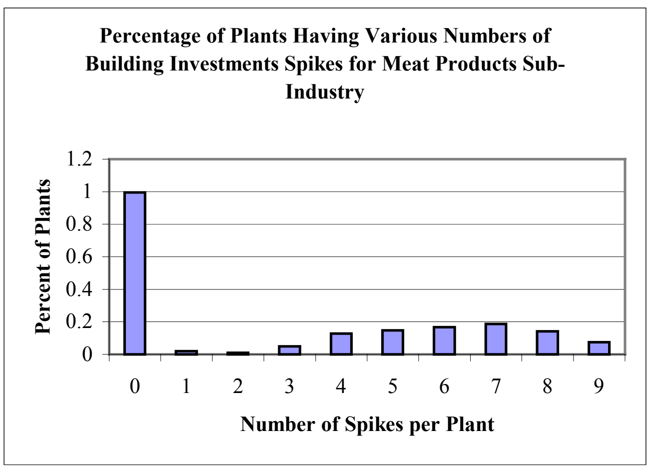


Figure 12. Absolute Spike Number for Machinery, Building and Combined Machinery and Buildings Investment Rates





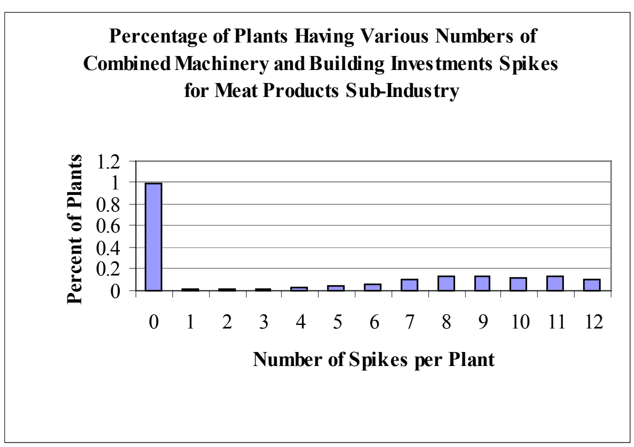
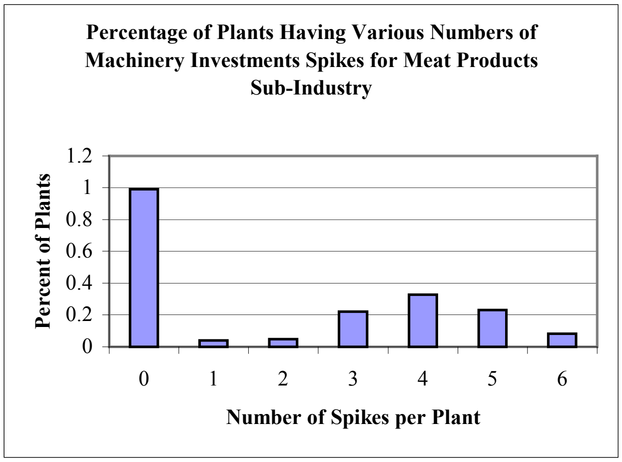
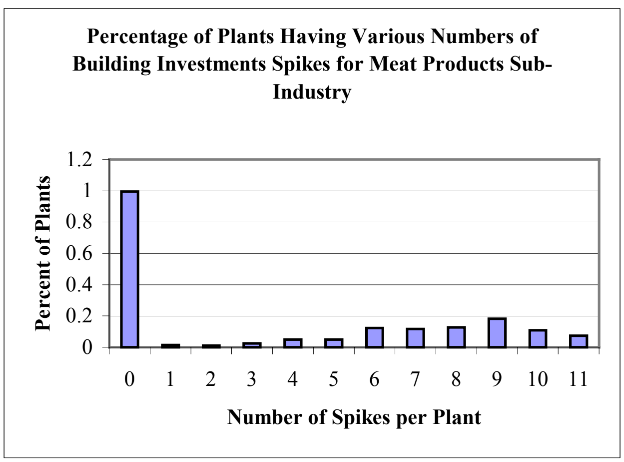


Figure 13. Relative Spike Number for Machinery, Building and Combined Machinery and Buildings Investment Rates





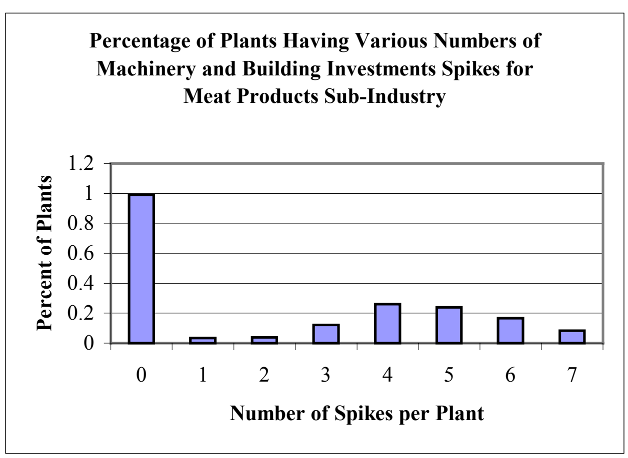
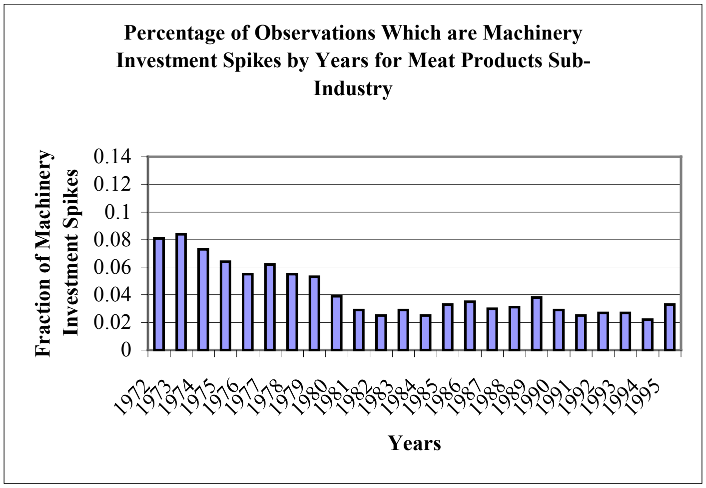
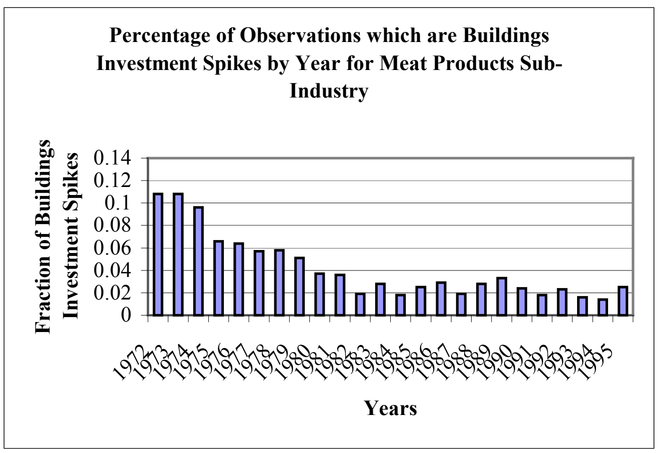


Figure 14. Absolute Spike Number by Years for Machinery, Building and Combined Machinery and Buildings Investment Rates





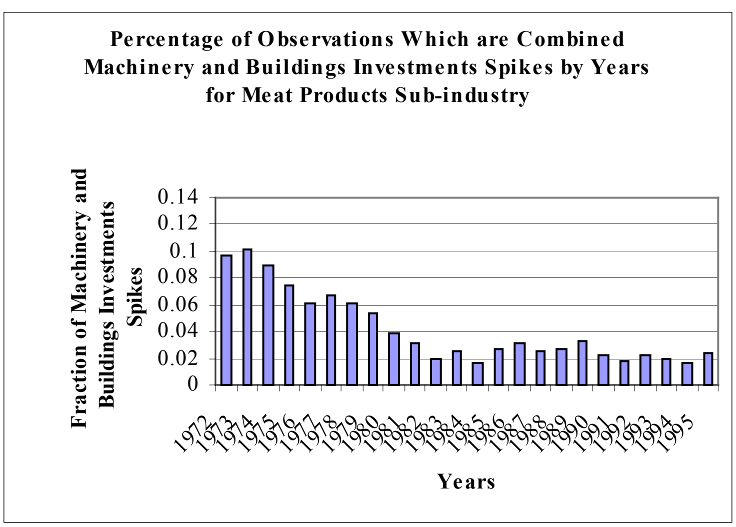


Figure 15. Relative Spike Number by Years for Machinery, Building and Combined Machinery and Buildings Investment Rates